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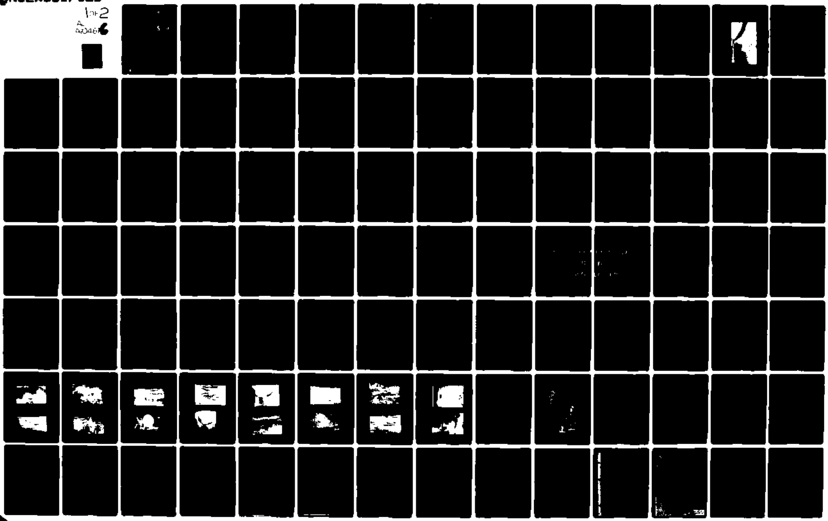

LEVEL II

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GRAND-CHARITON RIVER BASIN

ELMWOOD CITY LAKE DAM
SULLIVAN COUNTY, MISSOURI
MO. 10240

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PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

AD A104616

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7. AUTHOR(s) Consoer, Townsend and Associates, Ltd.		8. CONTRACT OR GRANT NUMBER(s) DACW43-79-C-0075
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Dam Safety, Lake, Dam Inspection, Private Dams

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report was prepared under the National Program of Inspection of Non-Federal Dams. This report assesses the general condition of the dam with respect to safety, based on available data and on visual inspection, to determine if the dam poses hazards to human life or property.

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DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

DEPARTMENT OF THE ARMY
ST. LOUIS DISTRICT, CORPS OF ENGINEERS
210 NORTH 12TH STREET
ST. LOUIS, MISSOURI 63101

IN REPLY REFER TO

SUBJECT: Elmwood City Lake Dam (Mo. 10240) Phase I Inspection Report

This report presents the results of field inspection and evaluation of the Elmwood City Lake Dam (Mo. 10240).

It was prepared under the National Program of Inspection of Non-Federal Dams.

This dam has been classified as unsafe, emergency by the St. Louis District because of conditions resulting from the separation at the joints of the primary (service) spillway pipe. The separation has caused saturation and piping of the soil, the formation of a sinkhole on the downstream toe above the pipe, and a 5-foot deep embankment slump.

In addition, it has been determined that the spillway/reservoir system of the dam can contain only 27 percent of the Probable Maximum Flood without overtopping and probable failure of the dam with a resultant loss of life downstream.

SUBMITTED BY: SIGNED — Chief, Engineering Division — 14 FEB 1980 Date

APPROVED BY: SIGNED — Colonel, CE, District Engineer — 14 FEB [illegible] Date

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ELMWOOD CITY LAKE DAM
SULLIVAN COUNTY, MISSOURI

MISSOURI INVENTORY NO. 10240

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

PREPARED BY
CONSOER, TOWNSEND AND ASSOCIATES, LTD.
ST. LOUIS, MISSOURI
AND
ENGINEERING CONSULTANTS, INC.
ENGLEWOOD, COLORADO
A JOINT VENTURE

UNDER DIRECTION OF
ST. LOUIS DISTRICT, CORPS OF ENGINEERS
FOR
GOVERNOR OF MISSOURI

DECEMBER 1979

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PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

Name of Dam:	Elmwood City Lake Dam, Missouri Inv. No. 10240
State Located:	Missouri
County Located:	Sullivan
Stream:	Elmwood Branch Creek
Date of Inspection:	August 10, 1979

Assessment of General Condition

Elmwood City Lake Dam was inspected by the engineering firms of Consoer, Townsend, and Associates, Ltd. and Engineering Consultants, Inc. (A Joint Venture) of St. Louis, Missouri according to the "Recommended Guidelines for Safety Inspection of Dams". These guidelines were developed by the Chief of Engineers, U.S. Army, Washington, D.C., with the help of Federal and State agencies, professional engineering organizations, and private engineers. The resulting guidelines are considered to represent a consensus of the engineering profession.

Based on the criteria in the guidelines, the dam is in the high hazard potential classification, which means that loss of life and appreciable property loss could occur in the event of failure of the dam. The estimated damage zone extends approximately five miles downstream of the dam. Within the damage zone are one railroad crossing, two highway crossings and the east edge of City of Milan affecting approximately ten buildings and dwellings, which may be subjected to flooding, with possible damage and/or destruction, and possible loss of life. Elmwood City Lake Dam is in the intermediate size classification since it is less than 40 feet high and impounds less than 50,000 acre-feet but more than 1,000 acre-feet of water.

The major deficiency with Elmwood City Lake Dam is the deteriorating condition of the downstream slope of the dam overlying the service spillway conduit. The 36-inch diameter conduit, which serves as the service spillway is in deplorable condition. The circumferential joints of the conduit are separated at three locations. A large sinkhole has developed on the downstream slope of the dam directly above the service spillway pipe. It is evident that the sinkhole has developed as a result of soil migration into the spillway through the separated joints. This condition gives concern to the stability of the dam embankment in the vicinity of the pipe.

Our hydrologic and hydraulic evaluation indicates that the existing spillways of Elmwood City Lake Dam do not meet the criteria set forth in the guidelines for a dam having the above size and hazard potential. Elmwood City Lake Dam, being an intermediate size dam with a high hazard potential, is required by the guidelines to pass the Probable Maximum Flood without overtopping. Since there is high hazard potential downstream of the dam, the appropriate spillway design flood for this dam is the Probable Maximum Flood. It was determined that the reservoir/spillway system can accommodate 27 percent of the Probable Maximum Flood without overtopping the dam. Our evaluation indicates that the reservoir/spillway system will accommodate the 100-year flood without overtopping.

The Probable Maximum Flood is defined as the flood discharge that may be expected from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible in the region. The 100-year flood is defined as a flood having a one percent chance of being equalled or exceeded during any given year.

Other deficiencies noted by the inspection team were the wave erosion on the upstream slope of the embankment near the crest; erosion on the downstream side along the left abutment contact; vegetation growing on the upstream slope; a need for periodic inspection by a qualified engineer and a lack of a maintenance schedule. The lack of a stability and seepage analyses on record is also a deficiency that should be corrected.

It is recommended that the owner take immediate action to correct the deteriorating condition of the downstream slope and the service spillway pipe. Other deficiencies should be corrected in the near future.

Walter G. Shifrin, P.E.

STATE OF MISSOURI
WALTER
G SHIFRIN
NUMBER
E-8834
REGISTERED PROFESSIONAL ENGINEER

Overview of Elmwood City Lake Dam

PHASE I INSPECTION REPORT

NATIONAL DAM SAFETY PROGRAM

ELMWOOD CITY LAKE DAM, I.D. No. 10240

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PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

ELMWOOD CITY LAKE DAM, Missouri Inv. No. 10240

SECTION 1: PROJECT INFORMATION

1.1 General

a. Authority

The Dam Inspection Act, Public Law 92-367 of August, 1972, authorizes the Secretary of the Army, through the Corps of Engineers, to initiate a national program of dam inspections. Inspection for Elmwood City Lake Dam was carried out under Contract DACW 43-79-C-0075 between the Department of the Army, St. Louis District, Corps of Engineers, and the engineering firms of Consoer, Townsend & Associates, Ltd., and Engineering Consultants, Inc. (A Joint Venture), of St. Louis, Missouri.

b. Purpose of Inspection

The visual inspection of Elmwood City Lake Dam was made on August 10, 1979. The purpose of the inspection was to make a general assessment as to the structural integrity and operational adequacy of the dam embankment and its appurtenant structures.

c. Scope of Report

This report summarizes the available pertinent data relating to the project; presents a summary of visual observations made during the field inspection; presents an assessment of hydrologic and hydraulic conditions at the site; presents an assessment as to the structural adequacy of the various project features; and assesses the general condition of the dam with respect to safety.

Subsurface investigations, laboratory testing, and detailed analyses were not within the scope of this study. No warranty as to the absolute safety of the project features is implied by the conclusions presented in this report.

It should be noted that reference in this report to left or right abutments is as viewed looking downstream. Where left abutment or left side of the dam is used in this report, this also refers to east abutment or side, and right to the west abutment or side.

d. Evaluation Criteria

Criteria used to evaluate the dam were furnished by the Department of the Army, Office of the Chief of Engineers, in the publication "Recommended Guidelines for Safety Inspection of Dams", Appendix D. These guidelines were developed with the help of several Federal agencies and many State agencies, professional engineering organizations, and private engineers.

1.2 Description of the Project

a. Description of Dam and Appurtenances

It should be noted that as-built drawings are not available for the dam or appurtenant structures. The following description is based upon observations and measurements made during the visual inspection and the limited design drawings.

The dam embankment is a compacted earthfill structure. The drawings show the crest width of the dam to be 15 feet. According to field measurement the crest width is approximately 26 feet. The elevation at the lowest point on the dam crest is approximately 879.8 feet above M.S.L., and the maximum height of the embankment was measured to be about 34 feet.

The downstream slope of the embankment was measured to be 1V to 3H. The upstream slope was near 1V to 1H from waterline to the dam crest. Some riprap was placed randomly on the upstream slope. The downstream slope was covered with grass. The crest of the dam is used as a roadway.

The geology in the vicinity of the dam and reservoir represents "recent" events in the geologic history of the area. Pleistocene glaciation filled the earlier drainages cut into bedrock and covered the surrounding hills leaving a near level plain. The present cycle of erosion has destroyed much of this plain with the new valleys not necessarily corresponding to the old drainages.

Nearly horizontal limestone and shale beds comprise the bedrock in the area. It is variably mantled by 10 to 200 feet of glacial moraine locally mantled by 1 to 2 feet of loess. In the stream valleys, reworked glacial materials cover either bedrock or morainal deposits and are represented topographically by flood plains and terraces.

There are two spillways for Elmwood City Lake Dam. The service spillway is a drop inlet structure located about 125 feet to the right of the left abutment. The drop inlet structure consists of a 10.5 foot high by 5 foot diameter steel pipe connected to a near horizontal 36-inch diameter steel pipe. The crest elevation of the service spillway is approximately 874 feet above M.S.L. The 36-inch pipe is approximately 174 feet long. The difference in elevation between the outlet invert and the crest of the spillway is about 28 feet.

The emergency spillway is an unlined excavated channel located along the left abutment. The bottom width of the spillway at its crest is about 80 feet. The side slopes of the spillway are approximately 1V to 14H. The crest elevation of the spillway is approximately 877 feet above M.S.L. The spillway discharge channel is approximately 300 feet long.

No low level drain outlet pipe is provided at the Elmwood City Lake Dam. A domestic water supply line 12-inches in diameter runs underneath the dam to a pumphouse located immediately downstream of the dam. The intake to the supply line is a flexible pipe attached to a float at the surface of the reservoir. The water supply line does not provide an adequate means for lowering the reservoir in case of an emergency.

b. Location

The dam is located on a southerly flowing, intermittant stream (Elmwood Branch) which joins the East Locust Creek approximately 3/4 mile downstream of the dam. The nearest downstream community is the City of Milan, which is about 2 miles downstream of the dam. The main access to the dam from Milan is north on Highway No. 6 approximately 1 mile, then north on Highway No. 5 approximately one mile, then about .5 mile to the dam. The dam and the lake are shown on the U.S.G.S. Milan East Quadrangle map (7.5 minute series), Missouri, in Section 35, Township 63 North, Range 20 West.

c. Size Classification

According to the "Recommended Guidelines for Safety Inspection of Dams", by the U.S. Department of the Army, Office of the Chief Engineer, the dam is classified in the dam size category as being "Intermediate" since its storage is more than 1,000 acre-feet but less than 50,000 acre-feet. The dam is classified as "Small" in dam size category because its height is less than 40 feet. The overall size classification is governed by the larger of the two determinations and the classification is accordingly "Intermediate" in size.

d. Hazard Classification

The dam has been classified as having "High" hazard potential in the National Inventory of Dams, on the basis that in the event of failure of the dam or its appurtenances, excessive damage could occur to downstream property, together with the possibility of the loss of life. Our findings concur with the classification. The estimated damage zone extends approximately five miles downstream of the dam. Within the damage zone are one railroad crossing, two highway crossings, and the east edge of City of Milan with approximately ten buildings and dwellings.

e. Ownership

Elmwood City Lake Dam is owned by the City of Milan. The mailing address is City of Milan, c/o Edward Sayre, Water Superintendent, Milan City Hall, Milan City, Missouri, 63556.

f. Purpose of Dam

The purpose of the dam is to impound water for domestic water supply and recreation.

g. Design and Construction History

The Elmwood City Lake Dam was constructed in 1972 by Hardy Construction Co. of Shelbyville, Missouri. No construction data were available from the contractor, however, a set of design drawings was made available from the Mayor of Milan, Mr. David Wilson.

The original design drawings were produced by Bernard Browing, P.E., of Fulton, Missouri.

According to the water superintendent, Edward Sayre, the original water supply intake control tower was pushed over from the pressure of ice formations. Mr. Sayre also stated that shortly after this occurred late in 1978 the present intake control structure was installed.

The only other reconstruction performed was a relocation of the emergency spillway channel to a point further away from the left abutment after the original spillway channel began eroding near the dam embankment.

h. Normal Operational Procedures

Normal operating procedure is to allow the reservoir to remain as full as possible with the level being controlled by rainfall, runoff, evaporation, and the elevation of the spillway crest. Also, the rate of consumption by the City of Milan and the surrounding community has an effect on the reservoir level.

The water superintendent, Mr. Sayre, remarked that the City of Milan has been obtaining all the water it needs from the reservoir by gravity flow. He also stated that he operates the supply pump periodically as part of the regular maintenance check.

1.3 Pertinent Data

a. Drainage Area (square miles):	6.41

b. Discharge at Damsite

Estimated experienced maximum flood (cfs):	NA
Estimated ungated spillway discharge with reservoir at top of dam elevation (cfs):	1772

c. Elevation (Feet above MSL)

Top of dam:	879.8
Spillway crest:	
Service Spillway	874.0
Emergency Spillway	877.0
Normal Pool:	874.0
Maximum Pool (PMF):	883.99

d. Reservoir

Length of pool at top of dam elevation (Feet):	15,600

e. Storage (Acre-Feet)

Top of dam:	4807
Spillway crest:	
Service Spillway	3131
Emergency Spillway	3940
Normal Pool:	3131
Maximum Pool (PMF):	6502

f. Reservoir Surface (Acres)

Top of dam:	330
Spillway crest:	
Service Spillway	250
Emergency Spillway	290
Normal Pool:	250

Maximum Pool (PMF):	385

g. Dam

Type:	Rolled Earthfill
Crest Length:	890 feet
Structural Height:	34 feet
Hydraulic Height:	34 feet
Crest width:	26 feet
Embenkment slopes:	
Downstream	1V to 3H
Upstream	1V to 1H from crest to waterline, remainder unknown
Zoning:	Unknown
Impervious core:	None according to design drawing
Cutoff:	Design drawings show a cutoff trench with a bottom width of 20 feet
Grout curtain:	Unknown

h. Diversion and Regulating Tunnel None

i. Spillway

Type:	
Service Spillway	Drop inlet
Emergency Spillway	Open channel
Length of crest:	
Service Spillway	5-foot diameter drop inlet pipe with a 3-foot diameter connecting pipe
Emergency Spillway	80 feet (bottom width of the trapezoidal channel)
Crest Elevation (feet above MSL):	
Service Spillway	874
Emergency Spillway	877

j. Regulating Outlets None

SECTION 2 : ENGINEERING DATA

2.1 Design

Design drawings were made available from the Mayor of the City of Milan, Missouri, Mr. David Wilson. The seven page set of design drawings is included as part of this report.

2.2 Construction

According to the Water Superintendent, Mr. Edward Sayre, the dam was built in 1972 by the Hardy Construction Co. of Shelbyville, Missouri. No construction records or as built drawings were available.

2.3 Operation

No operation records are available for the Elmwood City Lake Dam.

2.4 Evaluation

a. Availability

The availability of engineering data is fair and consists of State Geological Maps and U.S.G.S. quadrangle sheets along with the design drawings made available for this report. No information on design hydrology or hydraulic design was available, nor were seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams".

b. Adequacy

The conclusions presented in this report are based on field measurements, the available engineering data, past performance and present conditions of the dam. The data available is inadequate to evaluate the hydraulic and hydrologic characteristics related to the dam. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available, which is considered a deficiency. These seepage and stability analyses should be performed for appropriate loading conditions and made a matter of record.

c. Validity

A set of design drawings was made available for review. From field measurements, the dam appears to have been constructed more or less according to the available drawings, except for the fact that several structures have undergone reconstruction since the initial construction in 1972. The water superintendent, Mr. Sayre remarked that no construction supervision was provided when the dam was originally built.

SECTION 3: VISUAL INSPECTION

3.1 Findings

a. General

A visual inspection of the Elmwood City Lake Dam was made on August 10, 1979. The following persons were present during the inspection:

Name	Affiliation	Disciplines
Dr. M.A. Samad	Engineering Consultants, Inc.	Project Engineer, Hydraulics and Hydrology
Harry N. Cole	Engineering Consultants, Inc.	Civil, Structural and Mechanical
David J. Kerkes	Engineering Consultants, Inc.	Soils
Lynn Brown	Engineering Consultants, Inc.	Geology
Kevin Blume	Consoer, Townsend & Assoc., Ltd.	Civil and Structural
Everett Baker	Department of Natural Resources	

Don Sayre	City of Milan
Edward Sayre	City of Milan
Jim Cline	Private Contractr

Specific observations are discussed below.

b. Dam

The crest of the dam is about 26 feet wide and has a gravel road along its length. There were no cracks observed along the crest. While no significant deviations in horizontal alignment were apparent, noticeable settlement has occurred near the right abutment and to a lesser extent near the emergency spillway on the left abutment.

The upstream slope was near 1V to 1H and covered with riprap from the waterline to the crest, however, it was apparent that riprap did not extend far below the waterline. Erosion has occurred on the upstream slope due to wave action. Rubble concrete has been dumped to retard further erosion, however, not all the slope has been protected in this manner. A medium to heavy growth of vegetation as well as one young tree also exist near the top of the upstream slope. There were no tension cracks apparent along the upstream side of the crest or along the slope. There was no evidence of upstream slope movement.

The downstream slope was measured to be approximately 1V to 3H. The slope supported a good growth of grass, which appeared well maintained. Immediately over the service spillway conduit, piping of the embankment material into the conduit has resulted in the formation of a sinkhole in the slope. Evidence that the problem is getting progressively worse is given by the presence of five scarps within the sinkhole. The scarps indicate that the downstream slope has experienced movement on several occasions as a result of soil migration into the broken conduit and the formation of a cavity in the slope. The movement is gradually encroaching on the crest, however, tension cracks have not yet developed along the crest. The sinkhole was partially filled with water, however, the water has not precipitated slope movement downstream of the sinkhole at this time. While a few small depressions were observed elsewhere on the downstream slope, they are attributed to settlement and not to slope movement. There were no cracks observed on the downstream slope or near the downstream side of the dam crest. No seepage was observed exiting above the toe. Standing water was observed downtream of the toe of the slope, however, no boils or flowing seeps were apparent. There was no brush or trees growing on the slope and there was no evidence of burrowing animal activity.

Neither of the dam supporting abutments exhibit any signs of past or present instability. No cracks were observed along the abutment contacts. Some minor erosion was occurring along the downstream contact with the left abutment due to the lack of vegetative cover, however, no erosion was observed along any other contacts.

According to the "Missouri General Soil Map and Soil Association Descsription", 1979, published by the Soil Conservation Service, the materials in the general area of the dam belong to the soil series of Weller-Keswick-Lindley-Mandeville in the Central Mississipi Valley Wooded Slopes Forest. The soils are basically formed from loess, glacial till and weathered shale. The permeability of the soils range from slow to moderate.

No bedrock is exposed at the dam. Glacial moraine, consisting of a clay silt with some sand and fine gravel, crops out on the east side of the emergency spillway. The right abutment and reservoir valley slopes are covered by grasses which effectively masks the moraine. Soil development occurs on these slopes as well as on the flood plain downstream of the dam.

c. Appurtenant Structures

(1) Spillway

The service spillway is a drop inlet structure with a vertical 5-foot diameter steel pipe inlet and 36-inch diameter connecting steel conduit. The 36-inch conduit has separated in three locations. At a point about 42 feet from the outlet end the pipe has undergone a displacement in the horizontal direction of about 1-inch and about 1/2-inch in the vertical direction. The second break is located about 62 feet from the outlet end and exhibits a horizontal displacement of about 3-inches and vertical displacement of about 1-inch. The last break is located about 82 feet from the outlet end and has undergone about 1-inch horizontal displacement and 1-inch vertical displacement. The intake to the spillway is equipped with a trashrack and an anti-vortex device. The spillway was discharging less than 1/2 cfs at the time of the inspection.

The emergency spillway is located on the left abutment and is about 80 feet wide and approximately 300 feet long. The spillway channel supports a medium to light growth of grass. No significant erosion was noted in the spillway.

(2) Outlet Works

The outlet is a domestic water supply line which is a 12-inch diameter ductile iron pipe passing through the central part of the dam nearly 35 feet below the dam crest. The intake is attached to a float in the reservoir which in turn is connected to the supply line by a flexible pipe about 32 feet below the dam crest. This supply line does not provide an adequate means of lowering the reservoir in case of an emergency.

d. Reservoir Area

The water surface elevation was approximately 874 feet above MSL on the day of inspection.

The reservoir rim is gently sloped and no indication of instability or severe erosion was readily apparent. The slopes above the reservoir are heavily grassed. A few houses are built around the reservoir rim.

e. Downstream Channel

The service spillway discharges into a small pond immediately downstream of the dam. A small stream flows from the pond. The emergency spillway discharges into a small natural valley then flows into Elmwood Branch creek.

3.2 Evaluation

The following deficiencies were observed which affect the safety of the facility and require immediate corrective action.

1. The damage to the existing service spillway jeopardizes its intended function and its structural integrity.

2. The cavity developing in the downstream slope of the dam embankment above the spillway conduit and resultant collapse of the embankment slope into the cavity due to the migration of embankment material into the damaged service spillway conduit, poses an immediate danger to the safety of the dam.

Of a less serious nature are the following deficiencies:

1. Erosion of the upstream slope of the dam embankment near the crest and the erosion on the downstream side of the embankment along the left abutment contact, if allowed to continue, could jeopardize the structural stability of the embankment.

2. Vegetation on the upstream embankment slope, if allowed to continue to grow, could jeopardize the safety of the dam embankment. The root system of heavy vegetation makes potential avenues for piping through the embankment which in turn could affect the stability of the dam.

SECTION 4: OPERATIONAL PROCEDURES

4.1 Procedures

Elmwood City Lake Dam is used primarily for storage of domestic water and recreation. The water used by the City of Milan and the surrounding community is obtained by gravity flow from the reservoir through the 12-inch suppy line. A pump is provided in the water supply line near the downstream toe of the dam to operate in case of a pressure drop in the line. No operation is required for the spillway. The city water superintendent periodically checks the reservoir level, and if the intake apparatus needs to be lowered to maintain proper flow conditions, it is done manually with the winch provided on top of the floating platform.

4.2 Maintenance of Dam

The dam and the appurtenant structures are maintained by the City of Milan. Periodic checks are made by City personnel. Maintenance to the dam is performed by the City personnel on "as needed" basis.

There are no trees or shrubs growing on the downstream slope or crest of the structure. There was one very small tree noticed growing through the riprap near the right abutment on the upstream slope.

There is at this time, a problem with the service spillway pipe which is causing distress in the downstream slope of the embankment above this pipe. The City is considering corrective measures for the deteriorating condition of the spillway and the downstream slope of the embankment.

4.3 Maintenance of Operating Facilities

The only facilities at the damsite which can be operated are the 12-inch gate valve and a vertically mounted centrifugal pump located in the pumphouse near the toe of the dam. According to the water superintendent of the City of Milan, the pump has never been used to deliver water for municipal use. It is, however, periodically checked to insure that it is operable.

4.4 Description of Any Warning System in Effect

No warning system is in effect at this time, however, a system is presently being developed by the Department of Natural Resources and the City of Milan.

4.5 Evaluation

The condition of the spillway pipe and consequent distress in the downstream slope of the embankment present a serious stability problem with the dam.

The crest and the downstream slope of the dam appear to be adequately maintained. The riprap on the upstream slope should be improved. The vegetation growing in the emergency spillway discharge channel should be controlled.

SECTION 5: HYDRAULIC/HYDROLOGIC

5.1 Evaluation of Features

a. Design

The watershed of the Elmwood City Lake Dam upstream from the dam has an area of approximately 4100 acres. Most of the watershed area is pasture and meadow land with about 10 percent forest cover. Land gradients in the higher regions of the watershed average roughly 10 percent, and in the lower areas surrounding the reservoir average about 6 percent. The Elmwood City Lake Dam Reservoir is located on Elmwood Branch Creek, which joins East Locust Creek about 3/4 mile downstream of the reservoir. At its major axis, the watershed is approximately 3-1/2 miles long. A drainage map showing the watershed area is presented as Plate 1 in Appendix B.

Evaluation of the hydraulic and hydrologic features of Elmwood City Lake Dam were based on criteria set forth in the Corps of Engineers' "Recommended Guidelines for Safety Inspection of Dams", and additional guidance provided by the St. Louis District of the Corps of Engineers. The Probable Maximum Flood (PMF) was calculated from the Probable Maximum Precipitation (PMP) using the methods outlined in the U.S. Weather Bureau Publication, Hydrometeorological Report No. 33. The probable maximum storm duration was set at 24 hours, and storm rainfall distribution was based on criteria given in the Corps of Engineers EM 1110-2-1411 (Standard Project Storm). The Soil Conservation Service (SCS) method was used for deriving the unit hydrograph, utilizing the Corps of Engineers' computer program HEC-1 (Dam Safety Version). The unit hydrograph parameters are presented in Appendix B. The SCS method was also used for determining the loss rate. The hydrologic soil group of the watershed was determined from published soil maps. The hydrologic soil group of the watershed and the SCS curve number are presented in Appendix B. The curve number, the unit hydrograph parameters, the PMP index rainfall and the percentages for various durations were directly input to the HEC-1 (Dam Safety Version) computer program to obtain the PMF hydrograph. The computed peak discharges of the PMF and one-half of the PMF are 31,527 cfs and 15,763 cfs, respectively.

Both the PMF and one-half of the PMF inflow hydrographs were routed through the reservoir by the Modified Puls Method also utilizing the HEC-1 (Dam Safety Version) computer program. The reservoir was assumed at the service spillway crest level at the start of the routing computation. The peak outflow discharges for the PMF and one-half of the PMF are 25,882 cfs and 10,988 cfs, respectively. Both the PMF and one-half of the PMF when routed through the reservoir result in overtopping of the dam.

The size of physical features utilized to develop the stage-outflow relation for the spillways and overtop of the dam were determined from field notes, and sketches, prepared during the field inspection. The reservoir stage-capacity data were based on the U.S.G.S. Milan East Quadrangle topographic map (7.5 minute series). The combined spillways and dam overtop rating curve and the reservoir capacity curve are presented in Plates 2 & 3 respectively, in Appendix B.

From the standpoint of dam safety, the hydrologic design of a dam must aim at avoiding overtopping. Overtopping is especially dangerous for an earth dam because of its erosive characteristics. The safe hydrologic design of an embankment dam requires a spillway discharge capability, in combination with an embankment crest height that can handle a very large and exceedingly rare flood without dam overtopping.

The Corps of Engineers design dams to safely pass the Probable Maximum Flood that could be generated from the dam's watershed. This is the generally accepted criterion for major dams throughout the world, and is the standard for dam safety where overtopping would pose any threat to human life. Accordingly, the hydrologic requirement for safety for this dam is the capability to pass the Probable Maximum Flood without overtopping.

b. Experience Data

It is believed that records of reservoir stage or spillway discharge are not maintained for this site.

c. Visual Observations

Observations made of the spillway during the visual inspection are discussed in Section 3.1c(1) and evaluated in Section 3.2.

d. Overtopping Potential

As indicated in Section 5.1a, both the Probable Maximum Flood and one-half of the Probable Maximum Flood, when routed through the reservoir, resulted in overtopping of the dam. The peak outflow discharges for the PMF and one-half of the PMF are 25,882 cfs and 10,988 cfs, respectively. The PMF overtopped the dam crest by 4.19 feet and one-half of the PMF overtopped the dam crest by 2.17 feet. The total duration of embankment overflow is 10.50 hours during the PMF, and 6.88 hours during one-half of the PMF. The maximum capacity of the spillways with the reservoir at top of dam elevation is 1772 cfs. The spillways and the reservoir of Elmwood City Lake Dam are capable of accommodating a flood equal to approximately 27 percent of the PMF just before overtopping the dam. The spillway/reservoir system of Elmwood City Lake Dam will accommodate the 100-year flood without overtopping.

The failure of the dam could cause extensive damage to the property downstream of the dam and possible loss of life. The estimated damage zone extends approximately five miles downstream of the dam. Within the damage zone are one railroad crossing, two highway crossings and the eastern part of Milan where approximately ten buildings and dwellings are located.

SECTION 6: STRUCTURAL STABILITY

6.1 Evaluation of Structural Stability

a. Visual Observations

Depressions observed on the crest and downstream slope of the dam, exclusive of the sinkhole over the service spillway conduit, are in all probability the result of settlement and not indicative of slope movement. The sinkhole over the service spillway conduit is the result of a cavity which formed in the slope as embankment material migrated into a break in the conduit. Evidence that the condition is growing progressively worse is given by the presence of five scarps in the slope indicating continual piping. There is no reason to believe that the situation will improve, therefore, continued sloughing will occur as the cavity enlarges. At the time of the inspection, however, there were no tension cracks apparent along the crest above the sinkhole. The uppermost portion of the sinkhole was about 25 feet from the crest as measured along the slope. Standing water was observed in the sinkhole at the time of the inspection.

No seepage was observed on the downstream slope above the toe. Standing water was observed along the toe of the slope, however, no boils or flowing seeps were observed.

The erosion of the upstream slope on the right side of the dam was not serious enough to constitute an unsafe condition. Nevertheless, steps should be taken to repair existing damages and prevent further occurrences. The erosion along the left abutment contact downstream is of a less serious nature.

The spillway conduit has separated in three locations. At a point about 42 feet from the outlet, the pipe has undergone a horizontal displacement of about 1-inch and vertical displacement of about 1/2-inch. A second break is located about 62 feet from the outlet and exhibits a horizontal displacement of about 3-inches and a vertical displacement of 1-inch. Another break is located about 82 feet from the outlet and has undergone about 1-inch horizontal displacement and 1-inch vertical displacement.

b. Design and Construction Data

No design computations were uncovered during the report preparation phase. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available. Likewise, no embankment or foundation soil parameters are available for carrying out a conventional stability analysis on the embankment. No construction data or specifications relating to the degree of embankment compaction are available for use in a stability analysis.

c. Operating Records

No operating records are available relating to the stability of the dam or appurtenant structures. The water level in the reservoir remains close to full at all times. No regulating outlet works exists at the damsite.

d. Post Construction Changes

The emergency spillway was reconstructed in 1978 as a channel with a straight alignment, rather than curved as originally constructed, to eliminate erosion problems. The upstream dam embankment slope was riprapped above the waterline after the reservoir had filled and some embankment erosion had occurred.

e. Seismic Stability

The dam is located in Seismic Zone 1, as defined in "Recommended Guidelines for Safety Inspection of Dams" as prepared by the Corps of Engineers, and therefore, does not require a seismic stability analysis.

SECTION 7: ASSESSMENT/REMEDIAL MEASURES

7.1 Dam Assessment

The assessment of the general condition of the dam is based upon available data and visual inspections. Detailed investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I investigation, however, the investigation is intended to identify any need for such studies.

It should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with data available to the inspection team.

It is also important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through continued care and inspection can there be assurance that an unsafe condition could be detected.

a. Safety

The Elmwood City Lake Dam has serious stability problems and the dam is considered to be unsafe due to the deteriorating condition of the service spillway and the downstream slope overlying the spillway conduit.

The 36-inch diameter conduit, which serves as the service spillway, is in a deplorable condition and should be abandoned immediately in order to protect the integrity and safety of the dam. Of immediate concern is the large sinkhole on the downstream slope of the dam. This sinkhole having a diameter of over 25 feet is centered over the spillway about 25 feet from the downstream side of the roadway crest of the dam. The maximum depth of the sump is about five feet. Erosion of the embankment material into the spillway conduit has caused the sinkhole to develop on the downstream slope of the dam. Evidence that the problem is getting progressively worse is apparent from the presence of five scarps within the sinkhole. These scarps indicate that the downstream slope has experienced movement several times. Embankment settlement is gradually encroaching on the crest, however tension cracks have not yet developed along the crest. The scarps show embankment slippages of over one foot in depth.

The central part of the sinkhole is filled with water to a depth of about two feet and easily yields to penetration of a stick or pole. The presence of water in the sinkhole tends to reduce the stability of the slope as a result of seepage along the slope.

An internal inspection of the steel pipe revealed that the circumferential joints are separated at three locations. The joints are 20 feet apart and are offset about an inch in the vertical direction and are open from one to three inches in the horizontal direciton. One to two inch size rocks were exposed at one joint. The degree of erosion of the fill about the pipe at the joints was not determined. It is evident, however, from the sinkhole on the embankment surface, that considerable erosion has taken place about the pipe. An inspection at the periphery of the downstream end of the conduit showed dry conditions indicating that seepage or piping along the periphery of the conduit was not taking place. At the time of inspection, flow through the spillway conduit was less than 1/2 cubic feet per second and the discharge water was clear indicating no embankment erosion at the time. It is expected, however, that considerable erosion of embankment material about the pipe will take place when the pipe flows near full or under pressure conditions.

Our hydrologic and hydraulic calculations indicate that the existing spillway/reservoir system of Elmwood City Lake Dam is capable of accommodating a flood equal to approximately 27 percent of the Probable Maximum Flood without overtopping the dam. The spillway discharge capability of Elmwood City Lake Dam is considered to be "Seriously Inadequate" for a dam having a high hazard potential.

b. Adequacy of Information

Pertinent information relating to the design and construction of the dam and appurtenant structures is lacking. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available, which is considered a deficiency.

c. Urgency

The remedial measures recommended in Paragraph 7.2a should be accomplished immediately. The items recommended in paragraph 7.2b should be accomplished in the near future.

d. Necessity for Phase II Inspection

Based on the results of the Phase I inspection, and if the remedial measures recommended in Paragraph 7.2 are undertaken, a Phase II inspection is not felt to be necessary.

7.2 Remedial Measures

The remedial measures recommended in this section should be undertaken under the guidance of an engineer experienced in the design and construction of earth dams.

a. Immediate Remedial Measures:

The owner should take immediate action on the following measures in order to correct the safety problems with the dam:

(1) The downstream residents should be warned about the unsafe conditions at the dam and an emergency preparedness plan should be prepared immediately.

(2) The reservoir should be lowered immediately by several feet from the present level such that the safety of the structure is not jeopardized by a high water level. The reservoir should be maintained at a low level until the remedial measures listed in Paragraph 3 below are undertaken, at which time the reservoir should be lowered as needed to carry out the remedial measures.

(3) The downstream slope should be repaired, and the repairs may include the total removal of the spillway conduit and subsequent reconstruction of the slope or the spillway may have to be taken out of service. The appropriate course of action for repairing the downstream slope and to correct the problems with the spillway conduit should be determined by an engineer experienced in the design and construction of earth dams.

(4) A new service spillway should be constructed for the dam before the reservoir is filled. The combined discharge capability of the service spillway and the emergency spillway, in combination with the embankment crest height should be sufficient to handle the probable maximum flood.

b. The remedial measures which are of a less urgent nature are:

(1) Monitor the erosion on the upstream embankment slope and make repairs as required.

(2) Monitor the erosion on the downstream side along the left abutment contact and make repairs as required.

(3) Remove the vegetation growing on the upstream slope.

(4) Perform seepage and stability analyses for the dam embankment after developing reliable design parameters.

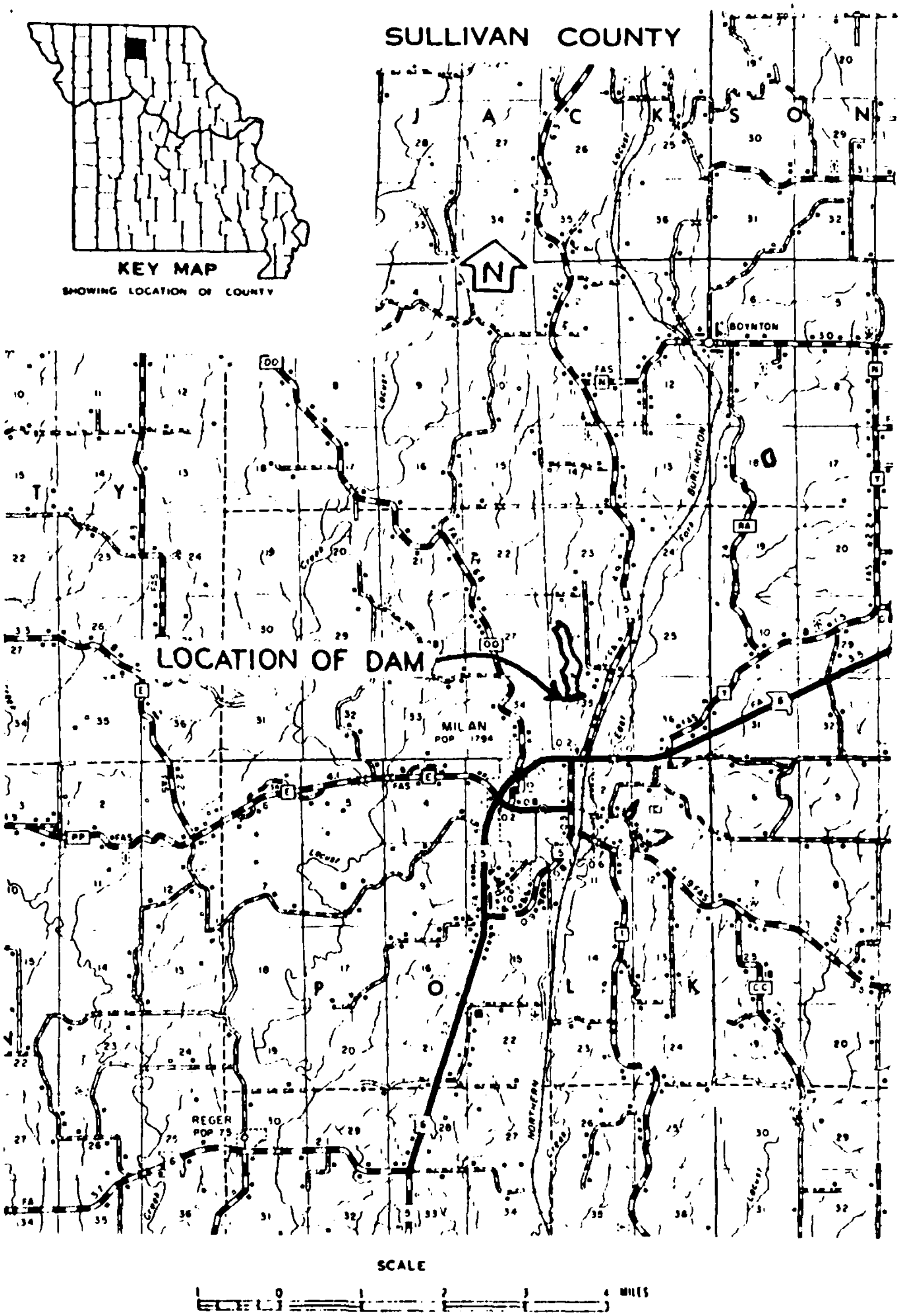
(5) The owner should initiate the following programs:

a. Periodic inspection of the dam by a professional engineer experienced in the design and construction of earthen dams.

b. Set up a maintenance schedule and log all visits to the dam for operations, repairs and maintenance.

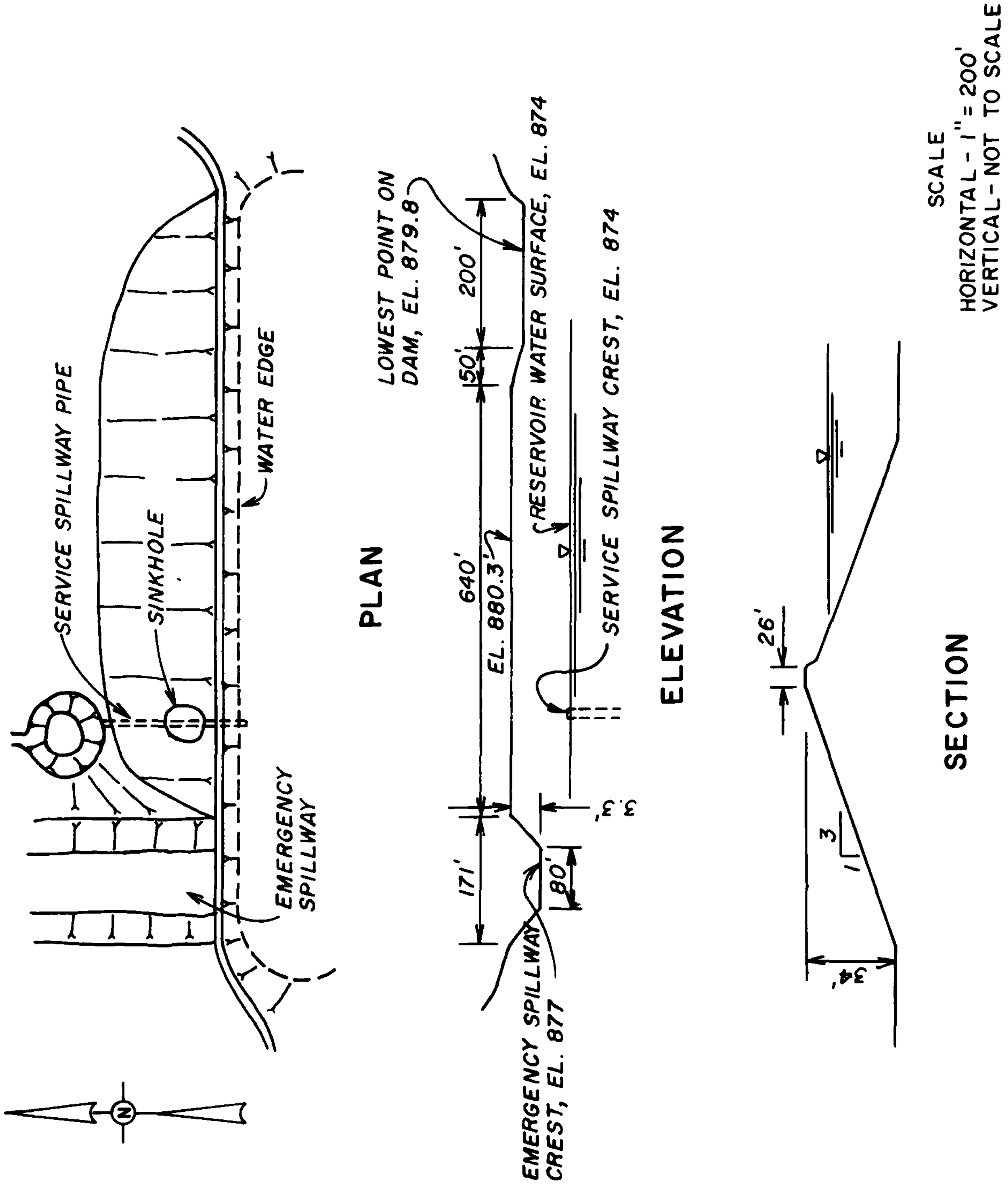
PLATES

1


SULLIVAN COUNTY
KEY MAP
SHOWING LOCATION OF COUNTY
J A C K S O N
N
BOYNTON
T Y
LOCATION OF DAM
MILAN
POP 1794
P O L K
REGER
POP 73
SCALE
MILES

LOCATION MAP – ELMWOOD CITY LAKE DAM

PLATE 2


SCALE
HORIZONTAL - 1" = 200'
VERTICAL - NOT TO SCALE
SERVICE SPILLWAY PIPE
SINKHOLE
WATER EDGE
EMERGENCY SPILLWAY
N
PLAN
LOWEST POINT ON DAM, EL. 879.8
200'
50'
640'
171'
EL. 880.3'
80'
3.3'
RESERVOIR WATER SURFACE, EL. 874
SERVICE SPILLWAY CREST, EL. 874
EMERGENCY SPILLWAY CREST, EL. 877
ELEVATION
26'
3
1
34'
SECTION

ELMWOOD CITY LAKE DAM (MO. 10240)
PLAN, ELEVATION & SECTION

WATER SUPP

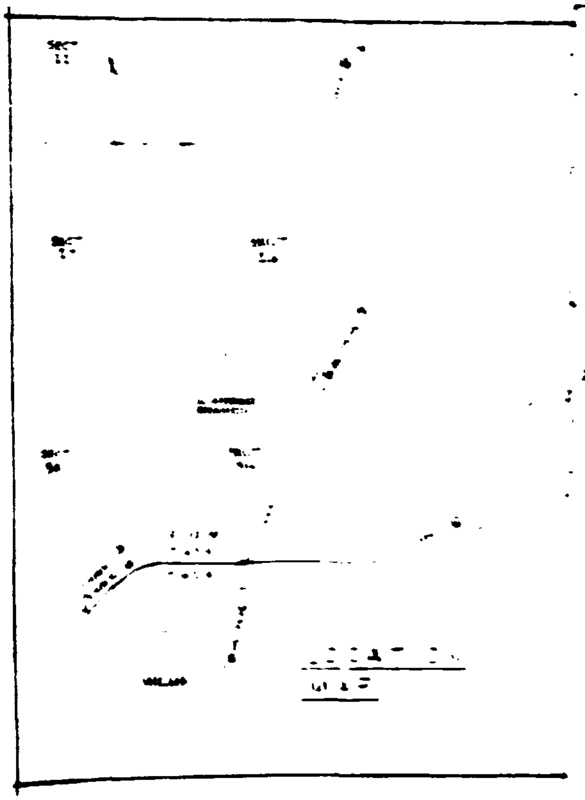
FOR

MILAN,

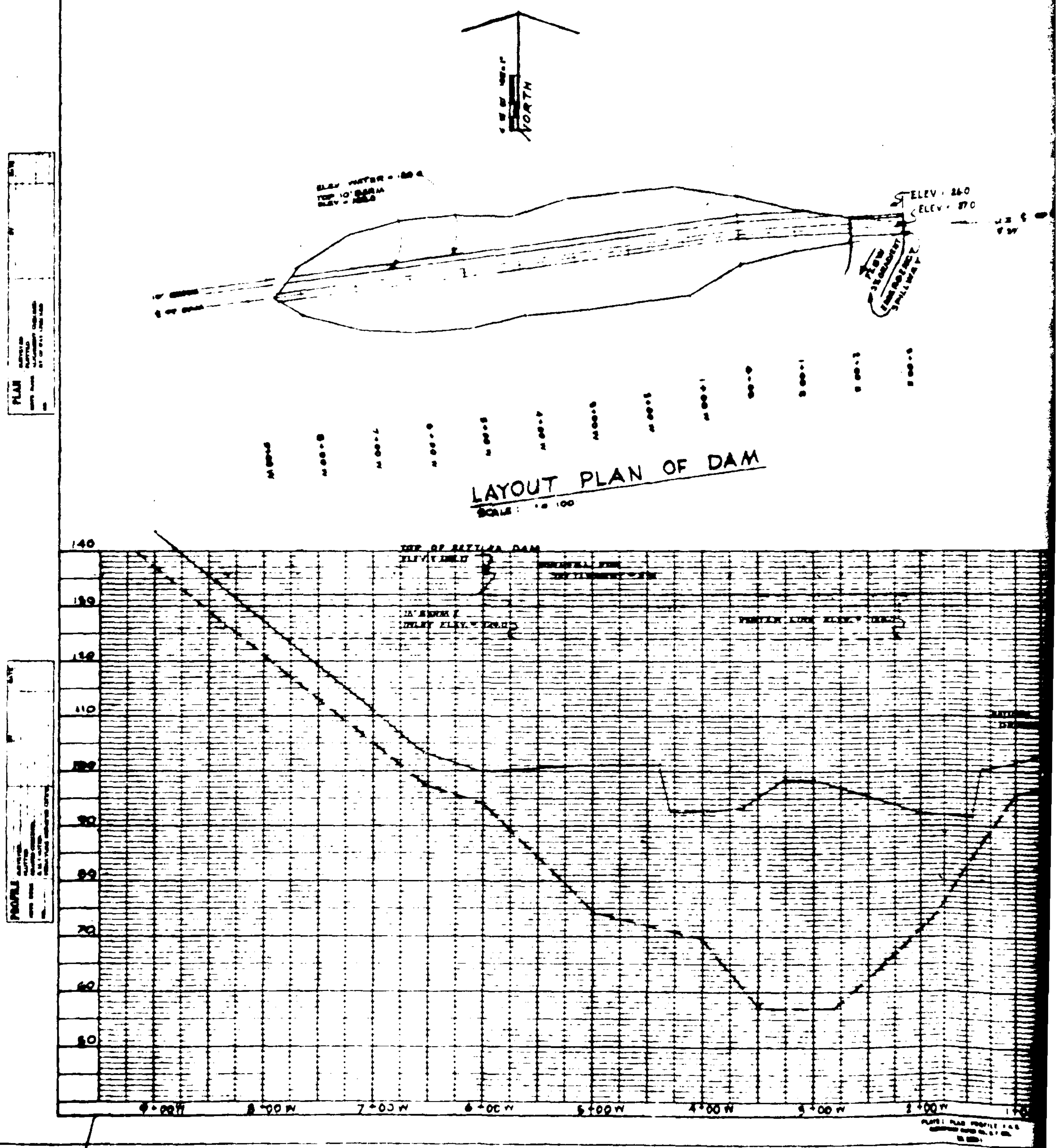
SUPPLY LAKE

FOR

LAN, MO.


SECT.
SECT.
SECT.
SECT.
SECT.
LOCATION MAP

BERNARD [illegible]
PROFESSIONAL [illegible]
FULTON [illegible]

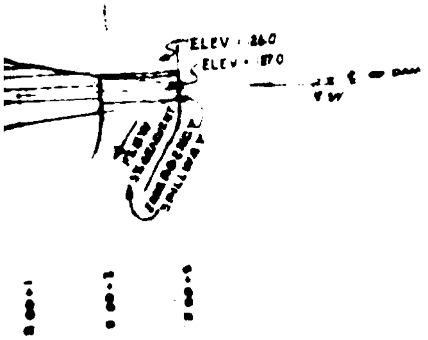


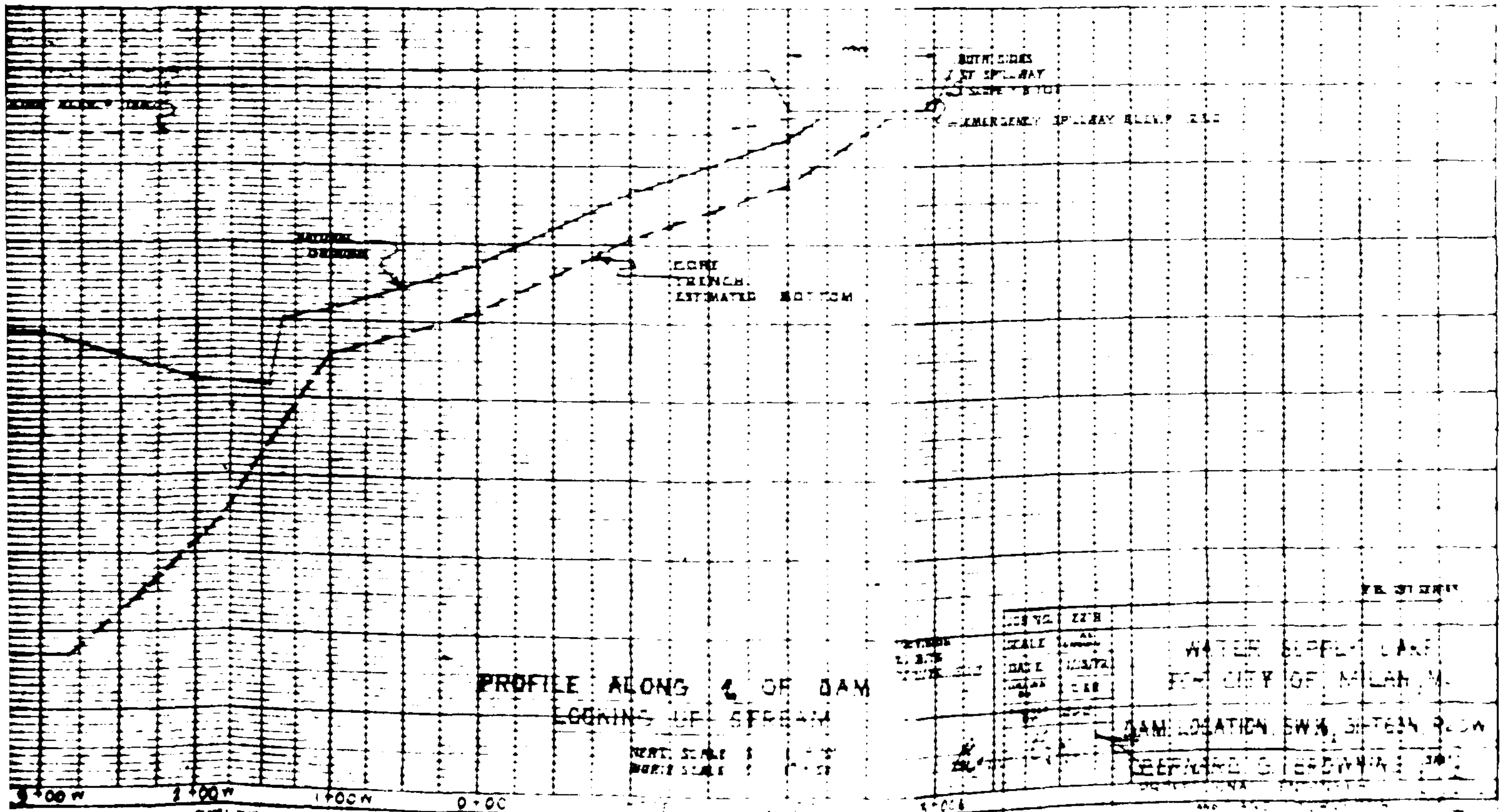
NORTH
ELEV = 260
ELEV = 270
FLOW
EMERGENCY SPILLWAY
TOP OF SETTLER DAM
INLET ELEV.
140
130
120
110
100
90
80
70
60
50
9+00 W
8+00 W
7+00 W
6+00 W
5+00 W
4+00 W
3+00 W
2+00 W
1+00

LAYOUT PLAN OF DAM

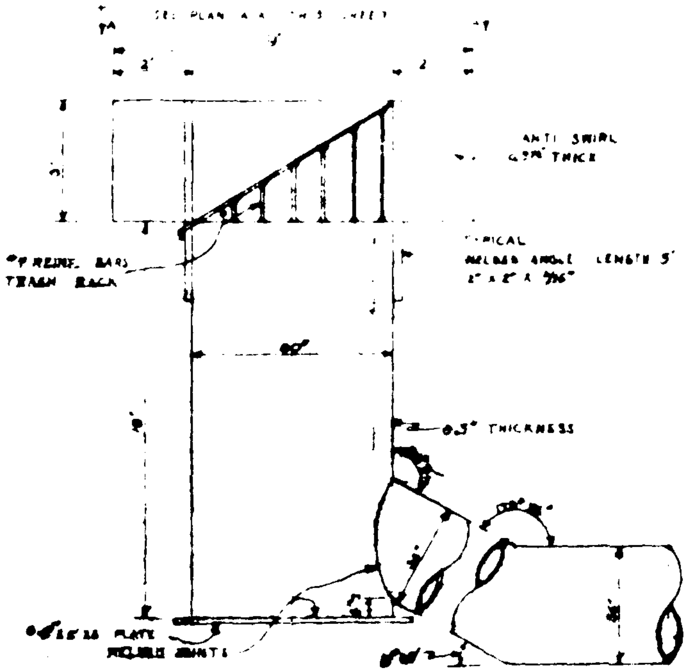
SCALE: 1:100

4


ELEV · 860
ELEV · 870
℄ OF DAM
SPILLWAY

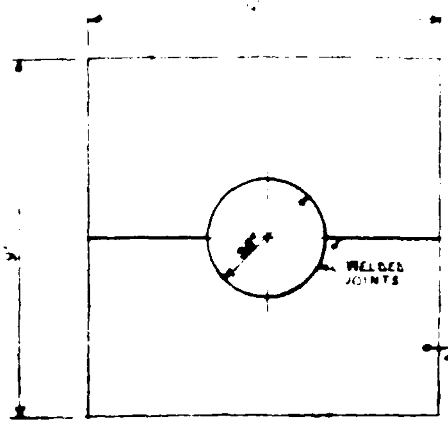

BOTH SIDES
SPILLWAY
EMERGENCY SPILLWAY ELEV.
NATURAL GROUND
CORE TRENCH
ESTIMATED BOTTOM
3+00 W
2+00 W
1+00 W
0+00
1+00 E
VERT. SCALE
HORIZ SCALE
SCALE
DATE
WATER SUPPLY LAKE
FOR CITY OF MILAN, M.
DAM LOCATION SW¼, [illegible] T63N R[illegible]W

PROFILE ALONG ℄ OF DAM
LOOKING UP STREAM


SEE PLAN A-A THIS SHEET
9'
2'
2
ANTI SWIRL
THICK
TYPICAL
WELDED ANGLE LENGTH 5'
#4 REINF. BARS
TRASH RACK
0.5" THICKNESS
PLATE
WELDED JOINTS

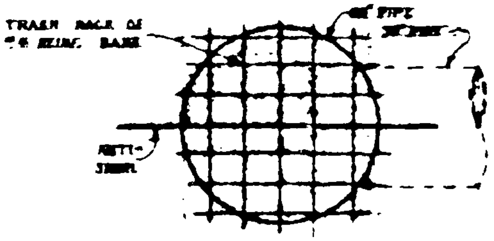
INLET & ELBOW DETAIL

SCALE


WELDED JOINTS
THICKNESS

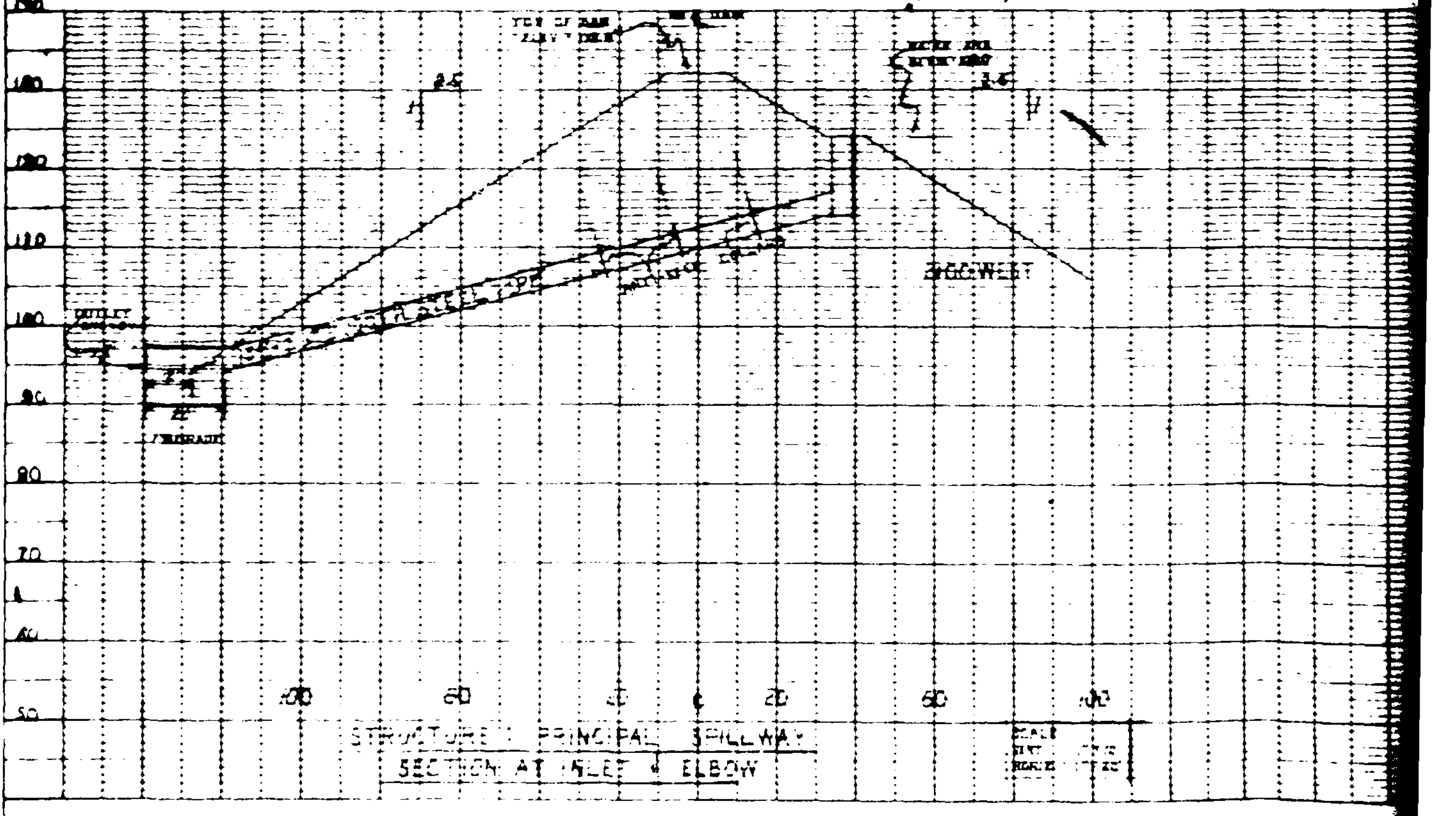
ANTI-SE

SCALE 1/2"


TRASH RACK OF #4 REINF. BARS
PIPE
ANTI-SWIRL

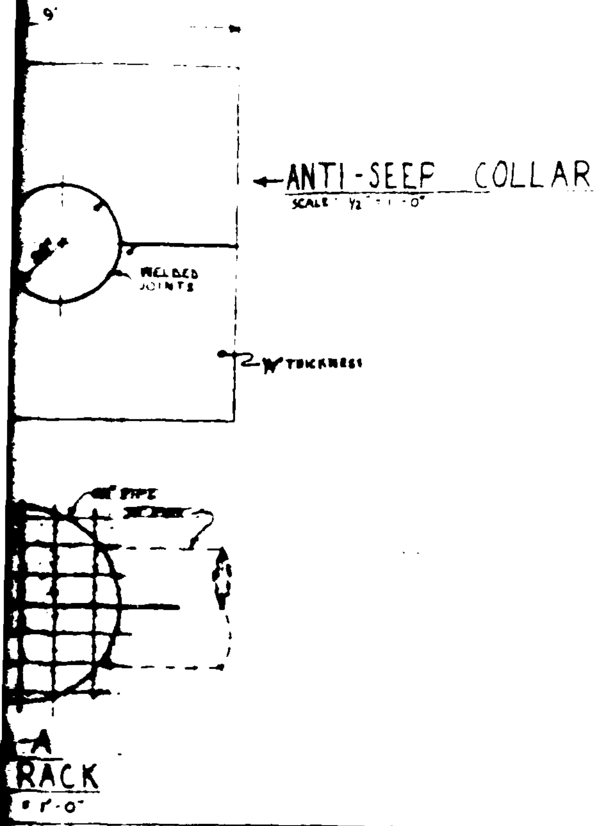
PLAN A-A
TRASH RACK

SCALE 1/2" = 1'-0"


140
130
120
110
100
90
80
70
60
50
TOP OF DAM
2.5
1
OUTLET
22'
STEEL PIPE
100
60
40
℄
20
50
100
SCALE

STRUCTURE 1 PRINCIPAL SPILLWAY
SECTION AT INLET & ELBOW

5


9'
ANTI-SEEP COLLAR
SCALE 1/2" = 1'-0"
WELDED JOINTS
THICKNESS
A
RACK
= 1'-0"

JOB NO: 2238

SCALE

DATE

WATER SUPPLY LAKE
FOR CITY OF MILAN, MO

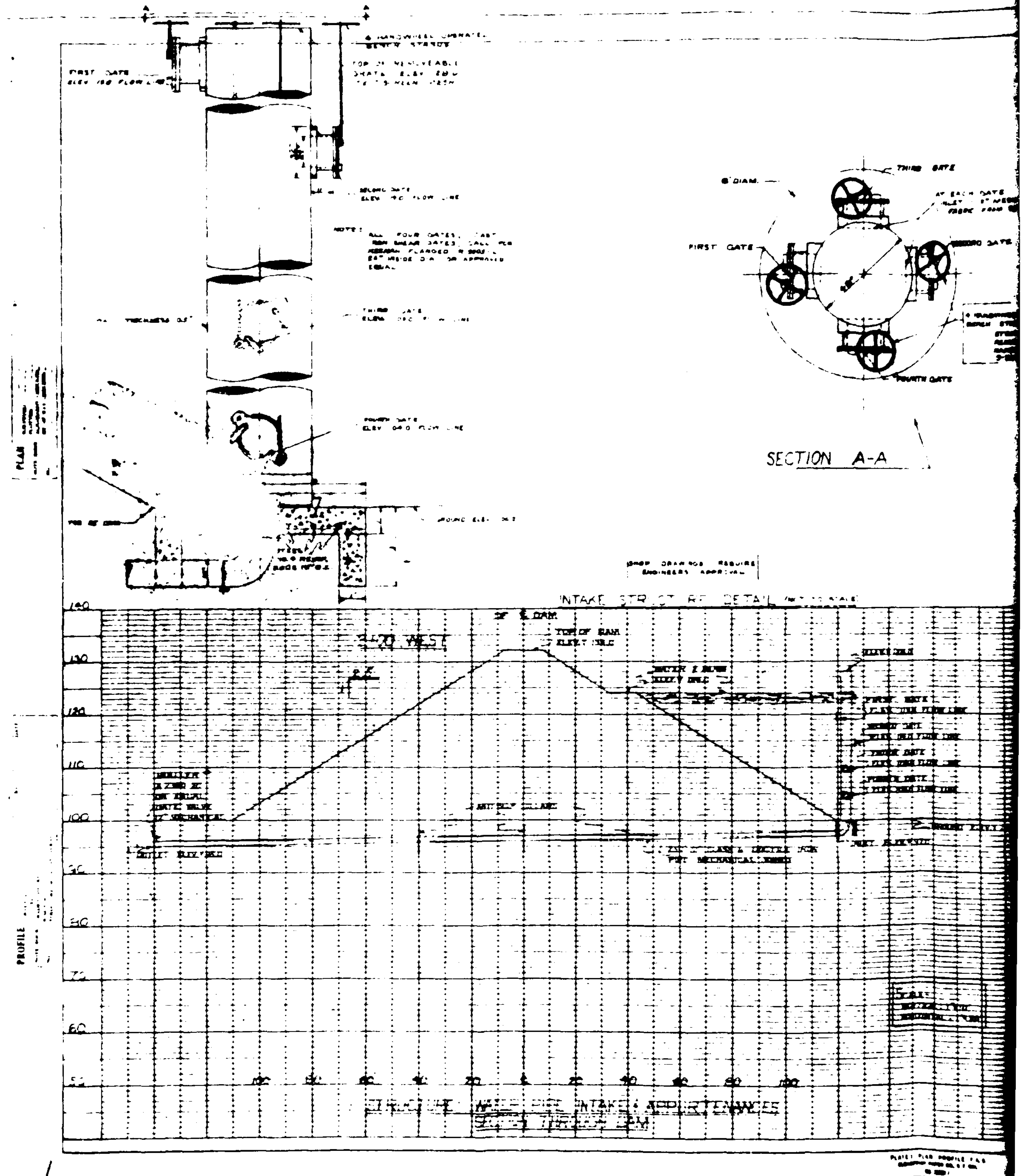
DAM LOCATION, SW¼, 31-T63N, R20W

E-2775

BERNARD G. BROWNING
PROFESSIONAL ENGINEER
AND SURVEYOR
FULTON, MISSOURI

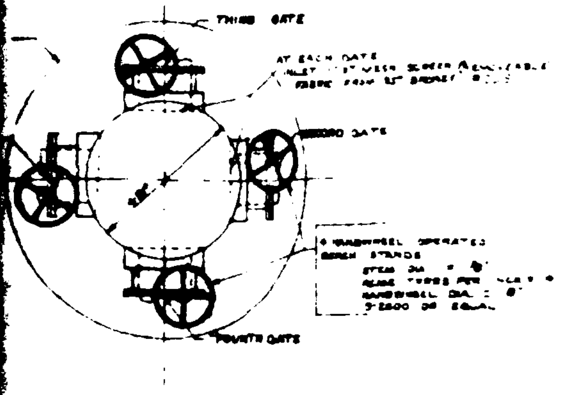
2

7


FIRST GATE
4 HANDWHEEL OPERATED BENCH STANDS
SECOND GATE
NOTE: ALL FOUR GATES, CAST IRON SHEAR GATES, CALL FOR ... FLANGED ... INSIDE DIA. OR APPROVED EQUAL
THIRD GATE
FOURTH GATE
GROUND ELEV.
SHOP DRAWINGS REQUIRE ENGINEERS APPROVAL
THIRD GATE
6' DIAM.
FIRST GATE
SECOND GATE
FOURTH GATE
PLAN
PROFILE
140
130
120
110
100
90
80
70
60
50
TOP OF DAM
TOP OF DAM
FIRST GATE
SECOND GATE
THIRD GATE
FOURTH GATE
OUTLET ELEV.
SCALE:
VERTICAL
HORIZONTAL

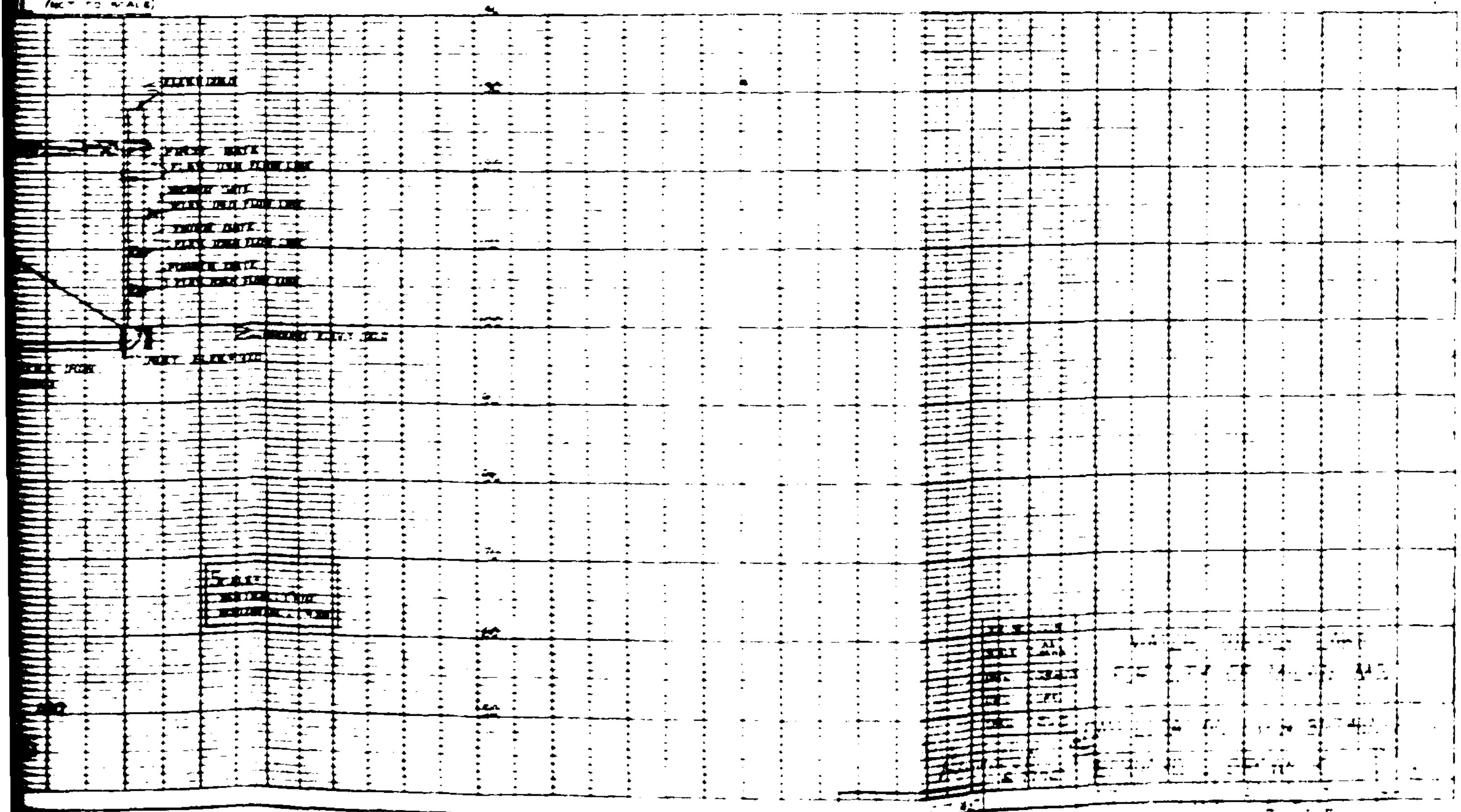
SECTION A-A

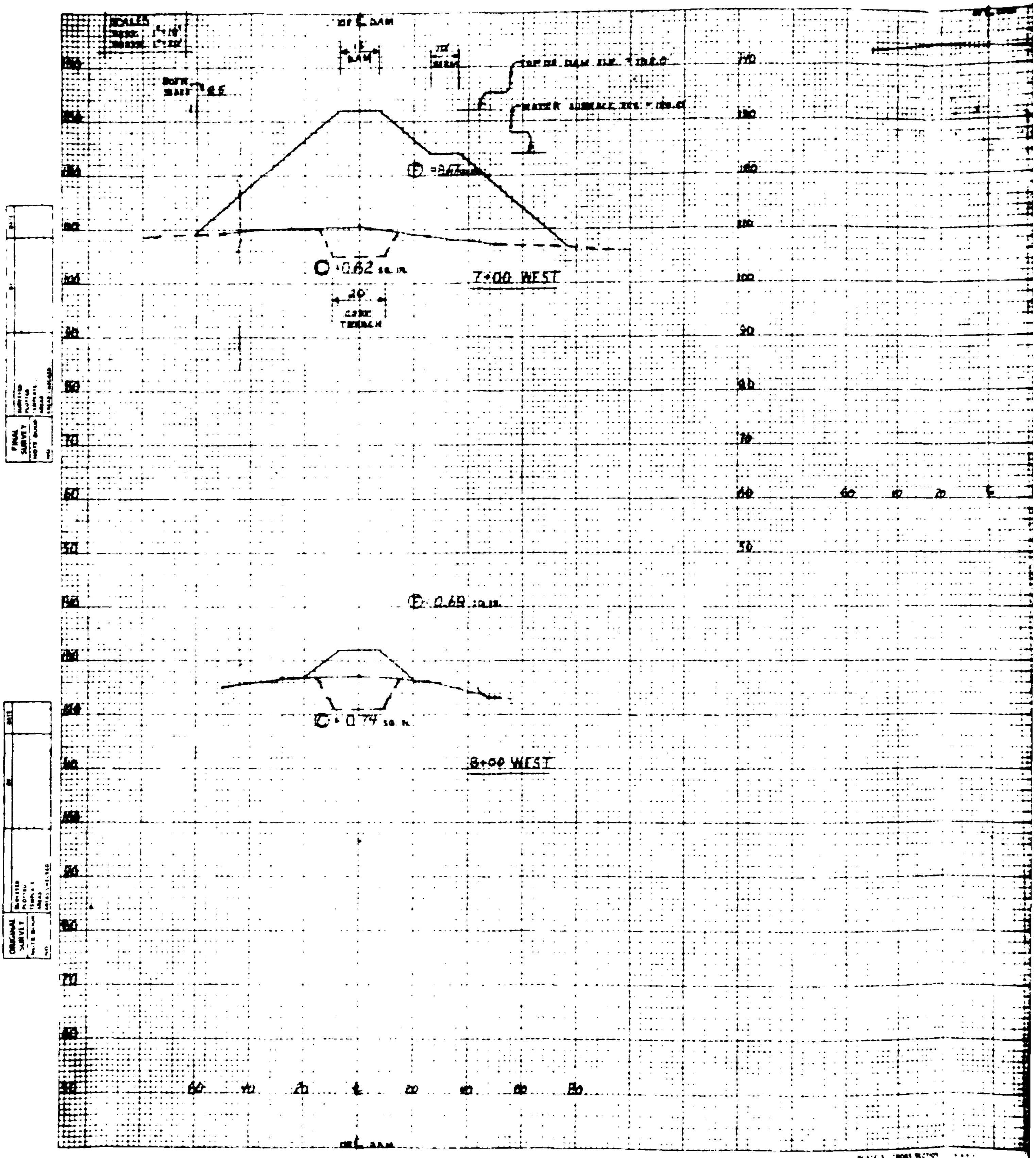
INTAKE STRUCTURE DETAIL


THIRD GATE
AT EACH GATE
SECOND GATE
4 HANDWHEEL OPERATED
BENCH STANDS
3-2800 OR EQUAL
FOURTH GATE

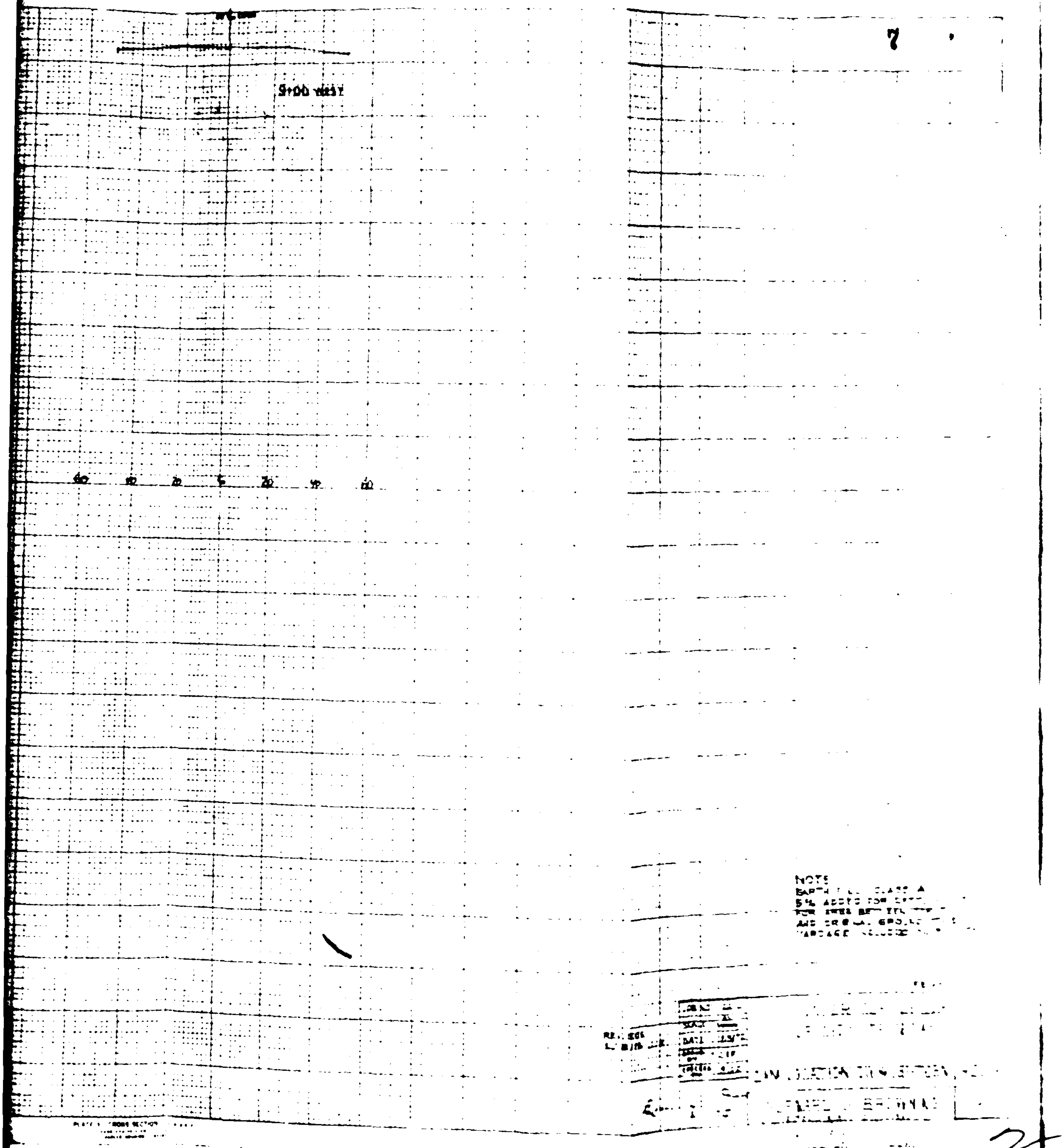
SECTION A-A

(NOT TO SCALE)


FIRST GATE
SECOND GATE
THIRD GATE
FOURTH GATE

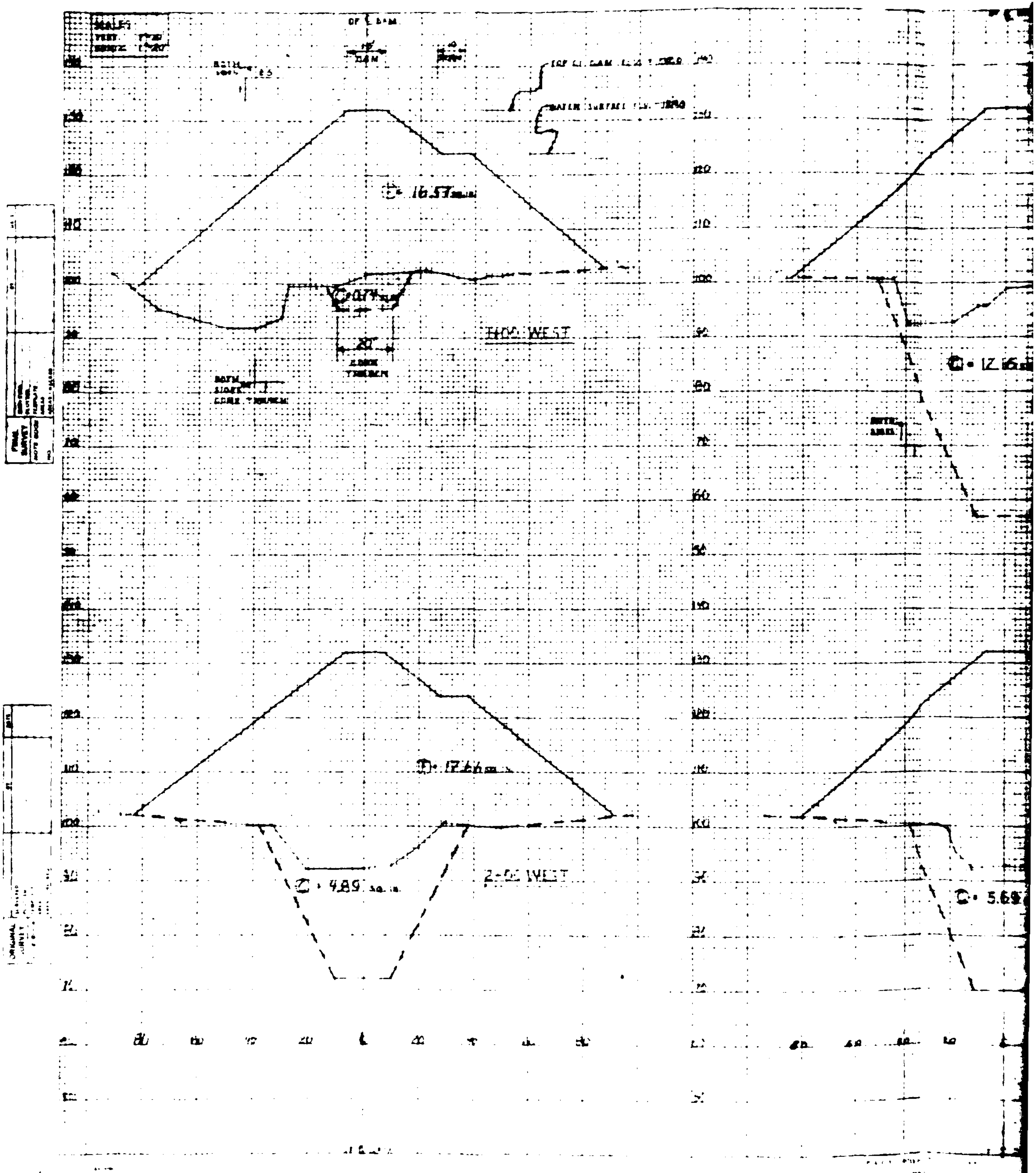

SCALES
OF ℄ DAM
15' DAM
TOP OF DAM ELE.
WATER SURFACE ELE.
Ⓕ =8.67
Ⓒ =0.62 SQ. IN.
7+00 WEST
20'
CORE TRENCH
Ⓕ 0.69 SQ. IN.
Ⓒ = 0.74 SQ. IN.
8+00 WEST
60
40
20
℄
20
40
60
80
110
100
90
80
70
60
50
℄ DAM
FINAL SURVEY
ORIGINAL SURVEY

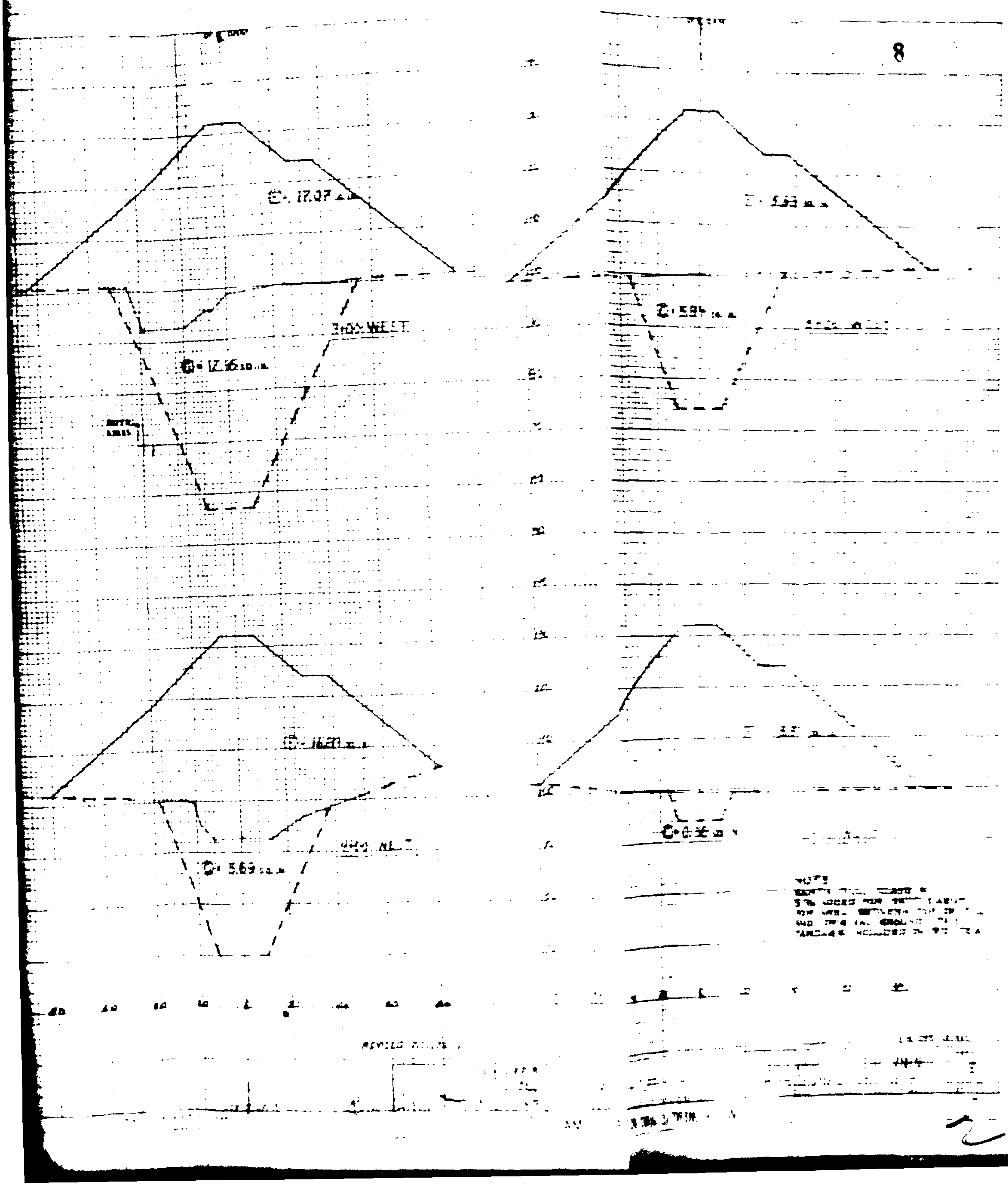
7

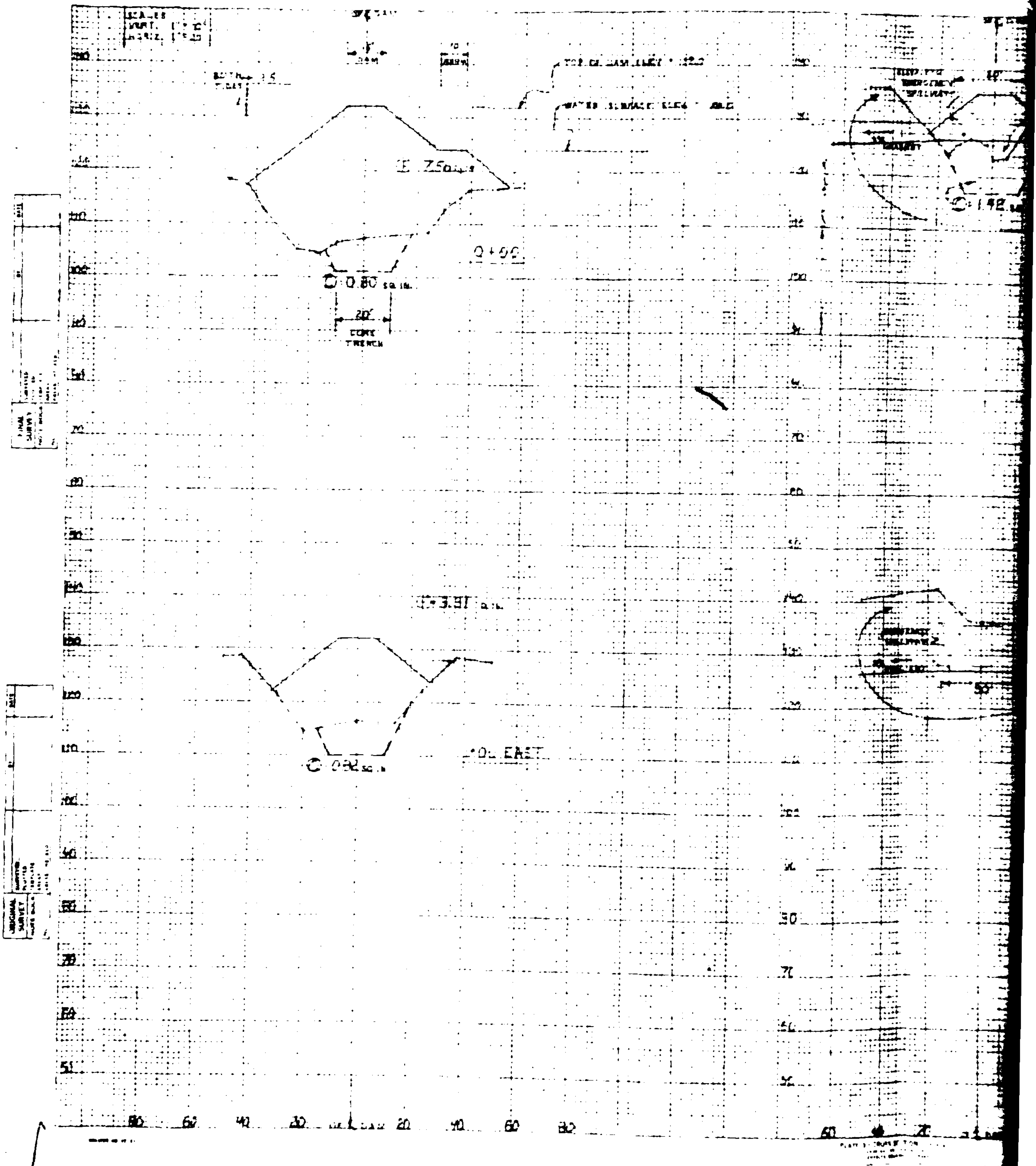

9+00 WEST
60
40
20
℄
20
40
60

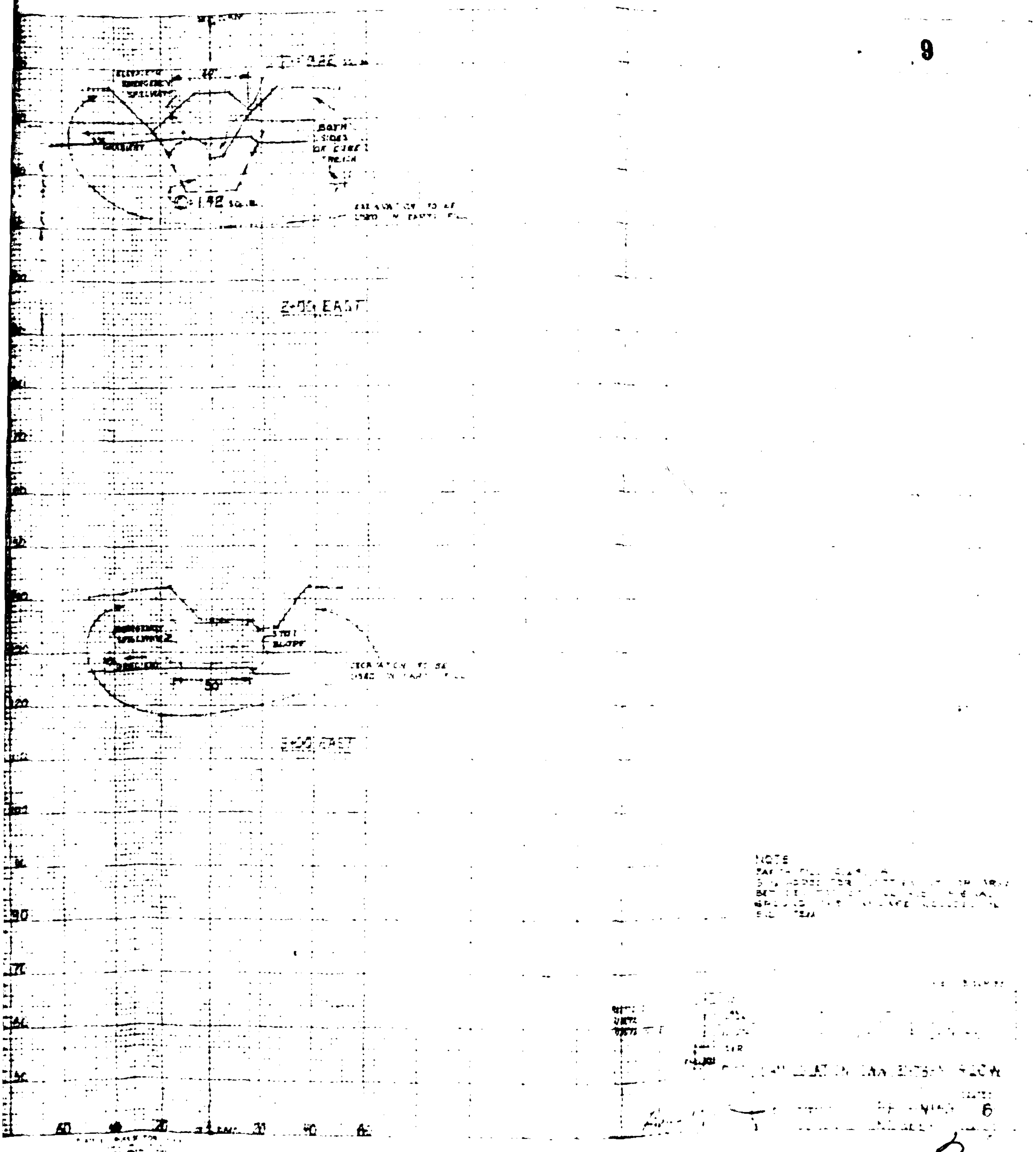
NOTE
EARTH [illegible] CLASS A
5% ADDED FOR [illegible]
FOR AREA BET[illegible]
AND ORIGINAL GROUND [illegible]
YARDAGE [illegible]

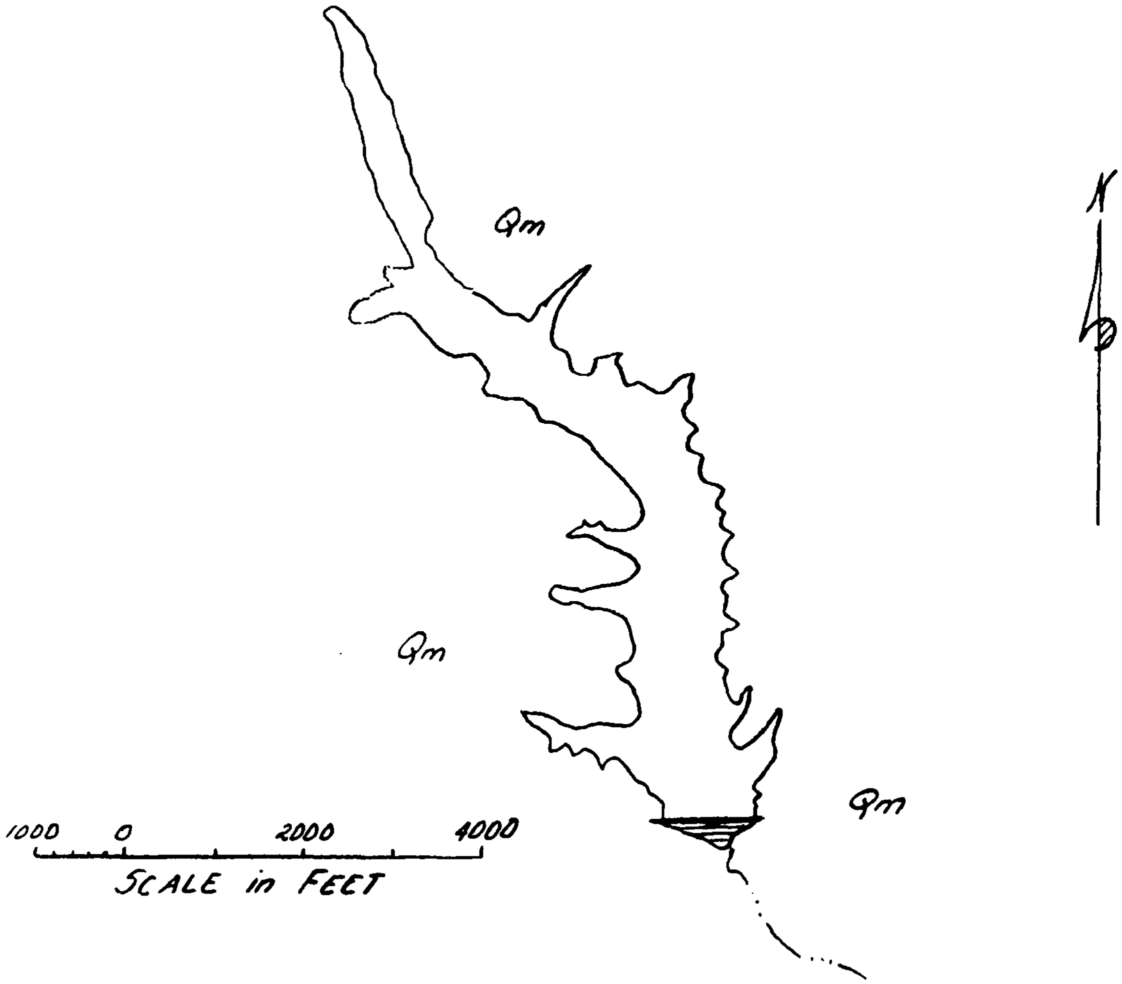
2

SCALES
VERT. 1"=20'
HORIZ. 1"=20'
OF ℄ DAM
DAM
TOP OF DAM ELEV.
WATER SURFACE ELEV.
BOTH SIDES
1:5
℄ = 16.57 sq.in.
℄ = 0.74 sq.in.
20'
CORE TRENCH
BOTH SIDES CORE TRENCH
1+00 WEST
℄ = 12.65
BOTH SIDES
℄ = 17.66 sq.in.
℄ = 4.89 sq.in.
2+00 WEST
℄ = 5.69
140
130
120
110
100
90
80
70
60
50
40
80
60
40
20
℄
20
40
60
80
FINAL SURVEY
ORIGINAL SURVEY


8
17.07
17.16 sq.m
WEST
5.69 sq.m
5.53 sq.m
5.84 sq.m
NOTE
5% ADDED FOR
AND ORIGINAL GROUND


SCALES
VERT.
HORIZ.
TOP OF DAM ELEV.
WATER SURFACE ELEV.
DAM
E 7.50 sq. in.
0+90
C 0.80 sq. in.
20'
CORE TRENCH
EMERGENCY SPILLWAY
C 1.42
C 0.82 sq. in.
E 3.81 sq. in.
EAST
EMERGENCY SPILLWAY
50'
80
60
40
20
20
40
60
80
60
40
20

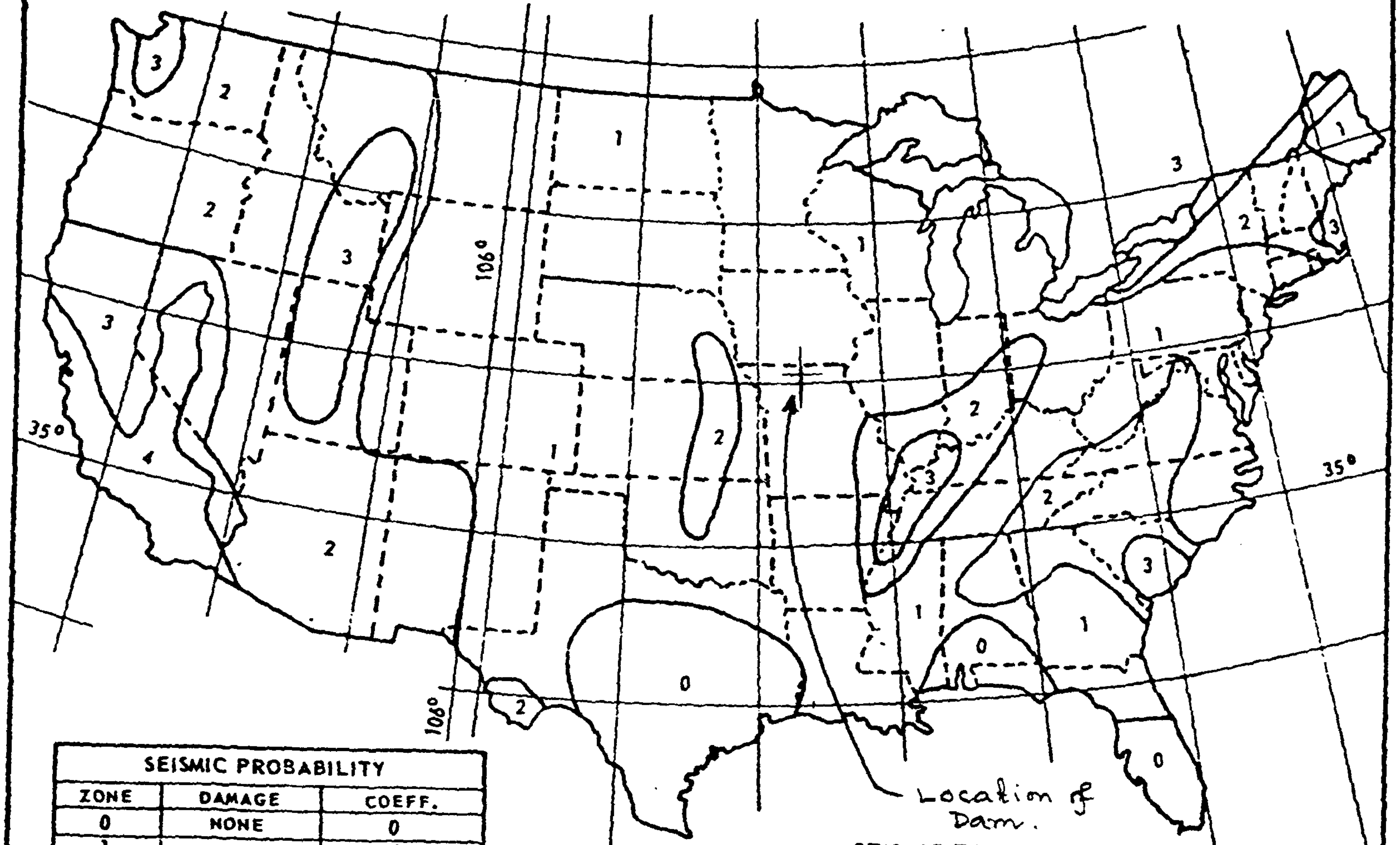

ELEVATED EMERGENCY SPILLWAY
C=1.42 sq.ft.
BOTH SIDES OF CREEK
2+00 EAST
EMERGENCY SPILLWAY 2
3 TO 1 SLOPE
58'
2+00 EAST
NOTE
60
20
30
40
60
6


Qm
Qm
Qm
N
1000 0 2000 4000
SCALE in FEET

LEGEND

Qm Glacial moraine; silt, clay, sand mixture with some small-size gravel. Locally mantled by thin veneer of loess.

Note: Pennsylvanian limestones and shales covered by 10 to 200 feet of moraine


35°
35°
106°
106°
0
0
0
1
1
1
1
1
2
2
2
2
2
2
2
2
3
3
3
3
3
3
3
4

Location of Dam.

SEISMIC PROBABILITY		
ZONE	DAMAGE	COEFF.
0	NONE	0
1	MINOR	0.025
2	MODERATE	0.05
3	MAJOR	0.10
4	GREAT	0.15

SEISMIC ZONE MAP
of
CONTIGUOUS STATES

Elmwood City Lake Dam
(Mo. 10240)

APPENDIX A

PHOTOGRAPHS TAKEN DURING INSPECTION

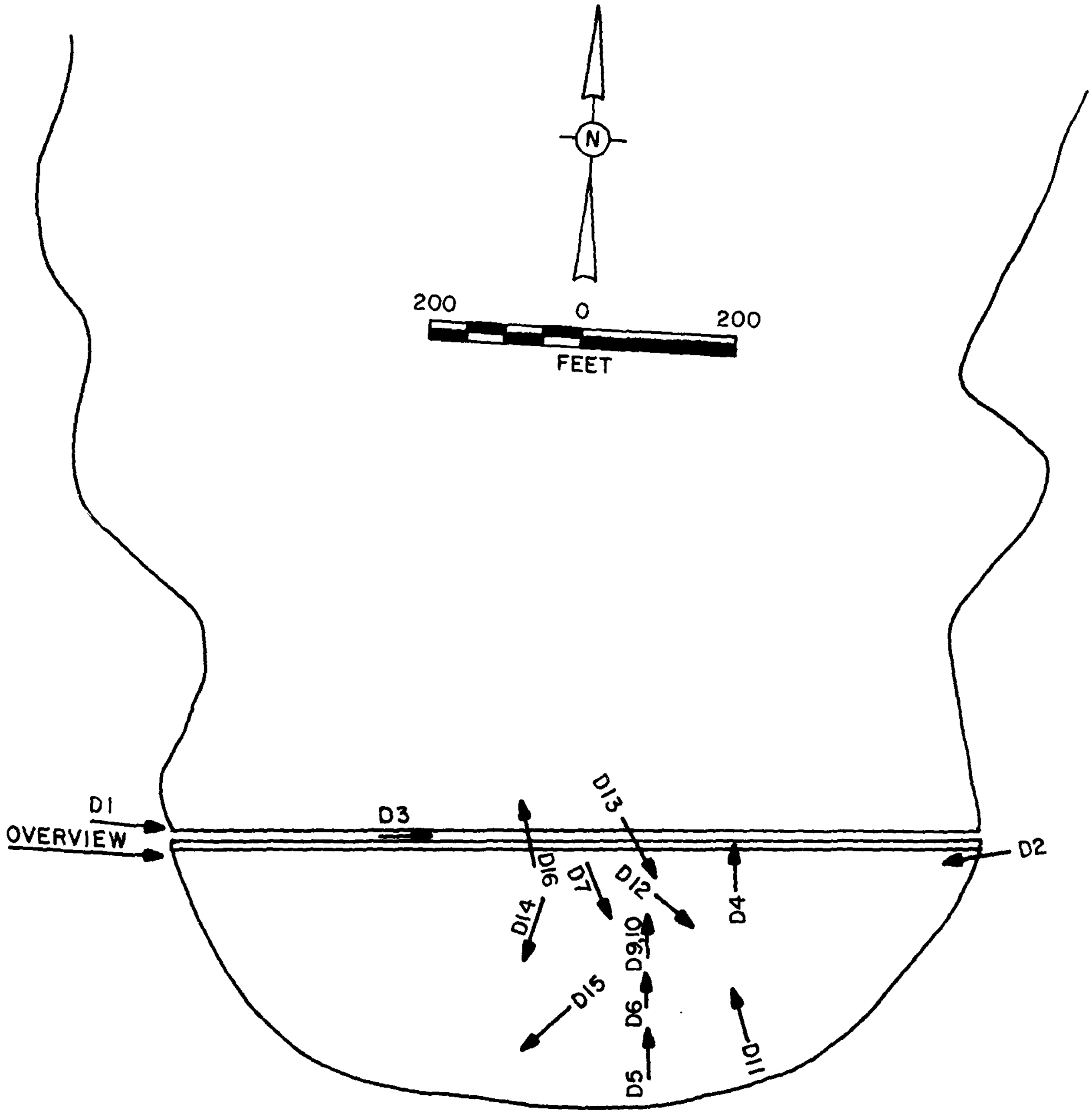

N
200
0
200
FEET
D1
OVERVIEW
D3
D13
D2
D16
D7
D12
D4
D14
D9,10
D15
D6
D5
D11

PHOTO INDEX
FOR
ELMWOOD CITY LAKE DAM

Elmwood City Lake Dam

D1. - View of upstream embankment slope.

D2. - View of downstream embankment slope.

D3. - Erosion on upstream embankment slope.

D4. - View of inlet of the service spillway.

D5. - View of outlet of the service spillway and the sinkhole overlying the spillway pipe.

D6. - Closeup view of the outlet of the service spillway.

D7. - View of the discharge pond of the service spillway.

D8. - View of the separation of service spillway pipe joint closest to the inlet.

D9. - Closeup view of joint separation depicted in Photo D8.

D10. - View of emergency spillway from left abutment.

D11. - View of the sinkhole overlying the service spillway pipe on the downstream embankment slope.

D12. - Standing water in the sinkhole.

D13. - View of slope movement above the sinkhole.

D14. - View of pumphouse immediately downstream of the dam.

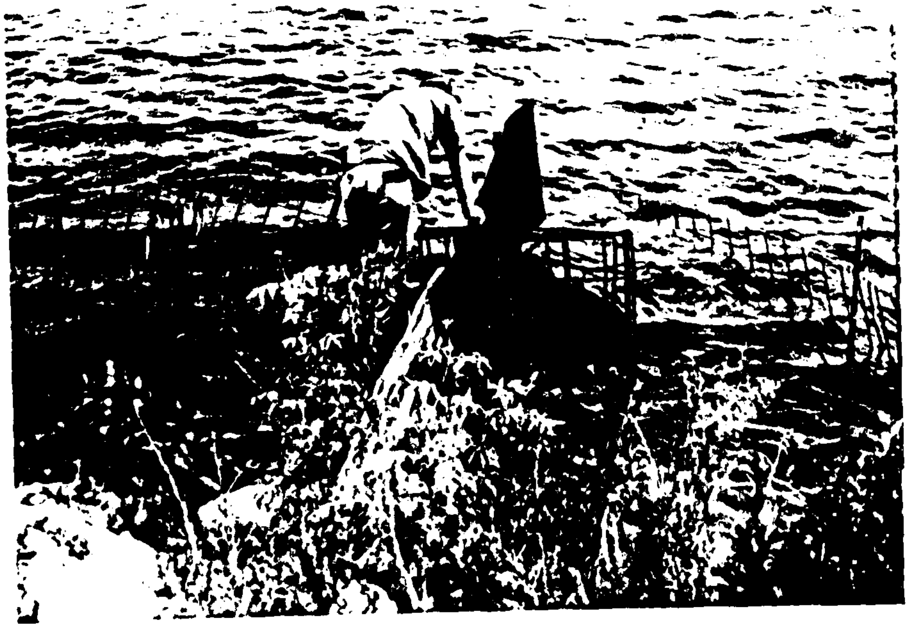
D15. - Inside view of the pumphouse.

D16. - View of the intake to the water supply line.

D1

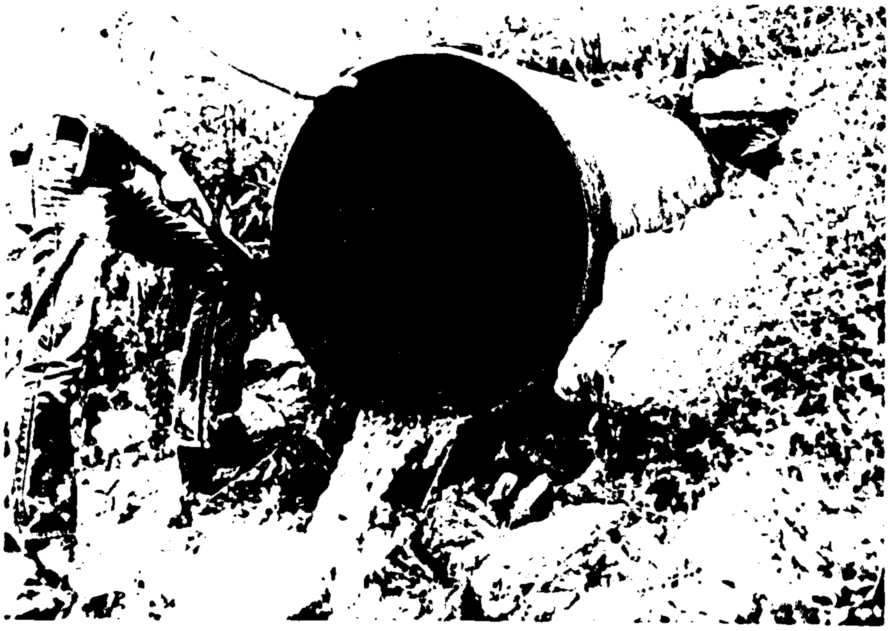
D2

D3



D4

D5



D6

D7

D8

D9

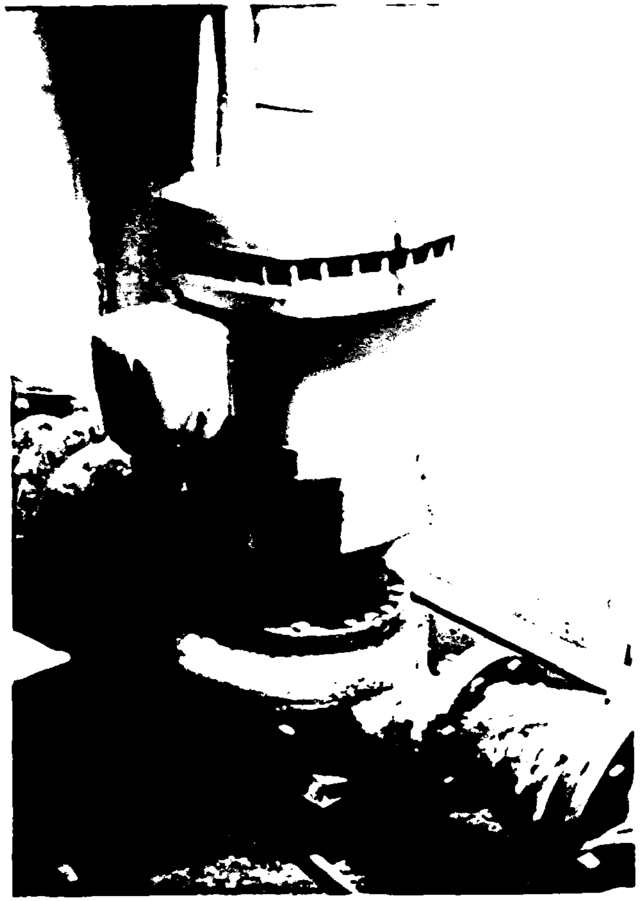
D10

D11

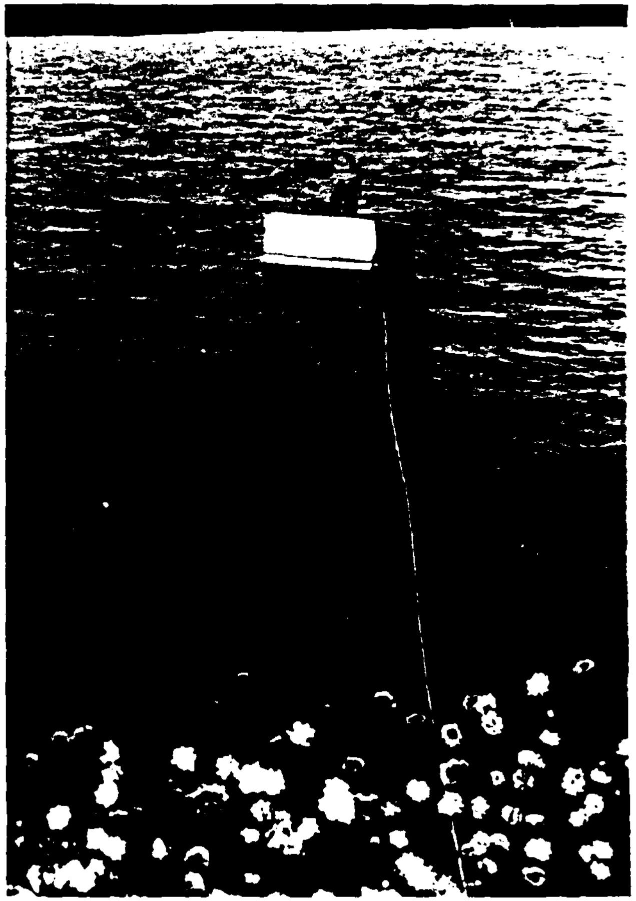
D12

D13

D14



B15

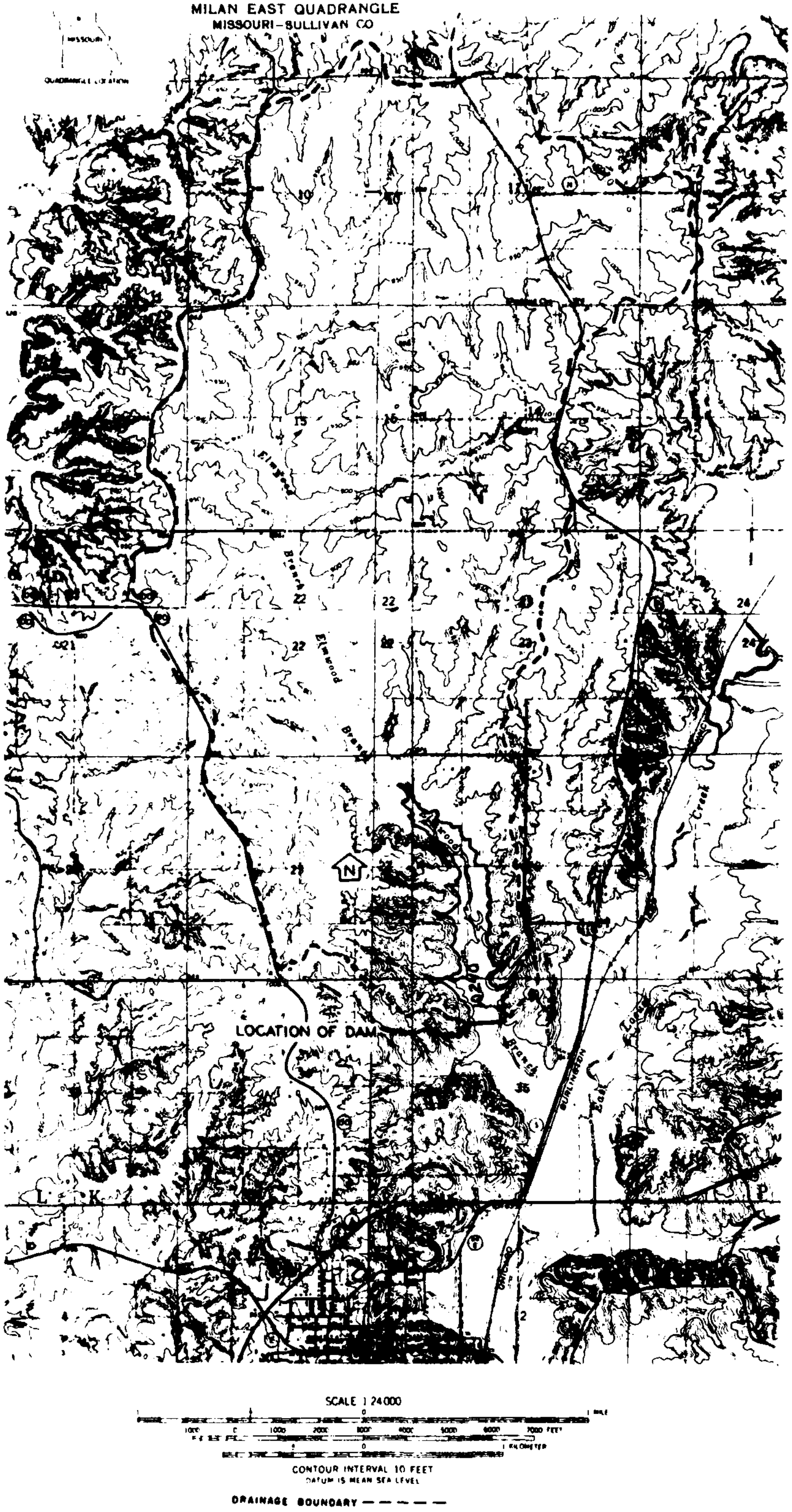


B16

APPENDIX B

HYDROLOGIC COMPUTATIONS

PLATE 1, APPENDIX B

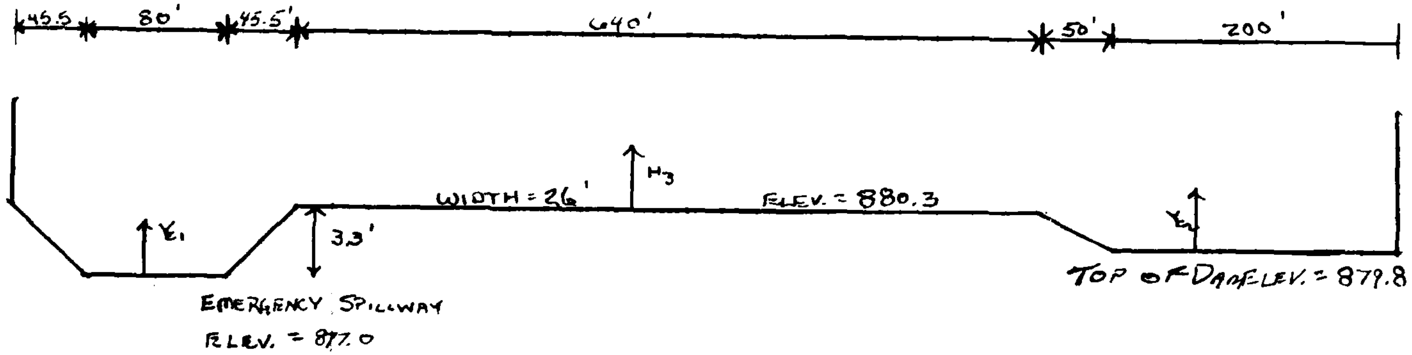

MILAN EAST QUADRANGLE
MISSOURI-SULLIVAN CO
MISSOURI
QUADRANGLE LOCATION
Elmwood Branch
LOCATION OF DAM
N
East Locust Creek
Burlington
SCALE 1:24000
1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 KILOMETER
CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL
DRAINAGE BOUNDARY — — — — —

ELMWOOD CITY LAKE DAM (MO 10240)
DRAINAGE BASIN

Dam Safety Inspection - Missouri SHEET NO. 1 OF

Elmwood City Lake Dam JOB NO. 1240-001-1

Spillway and Overtop Rating Curve BY RW DATE 9-18

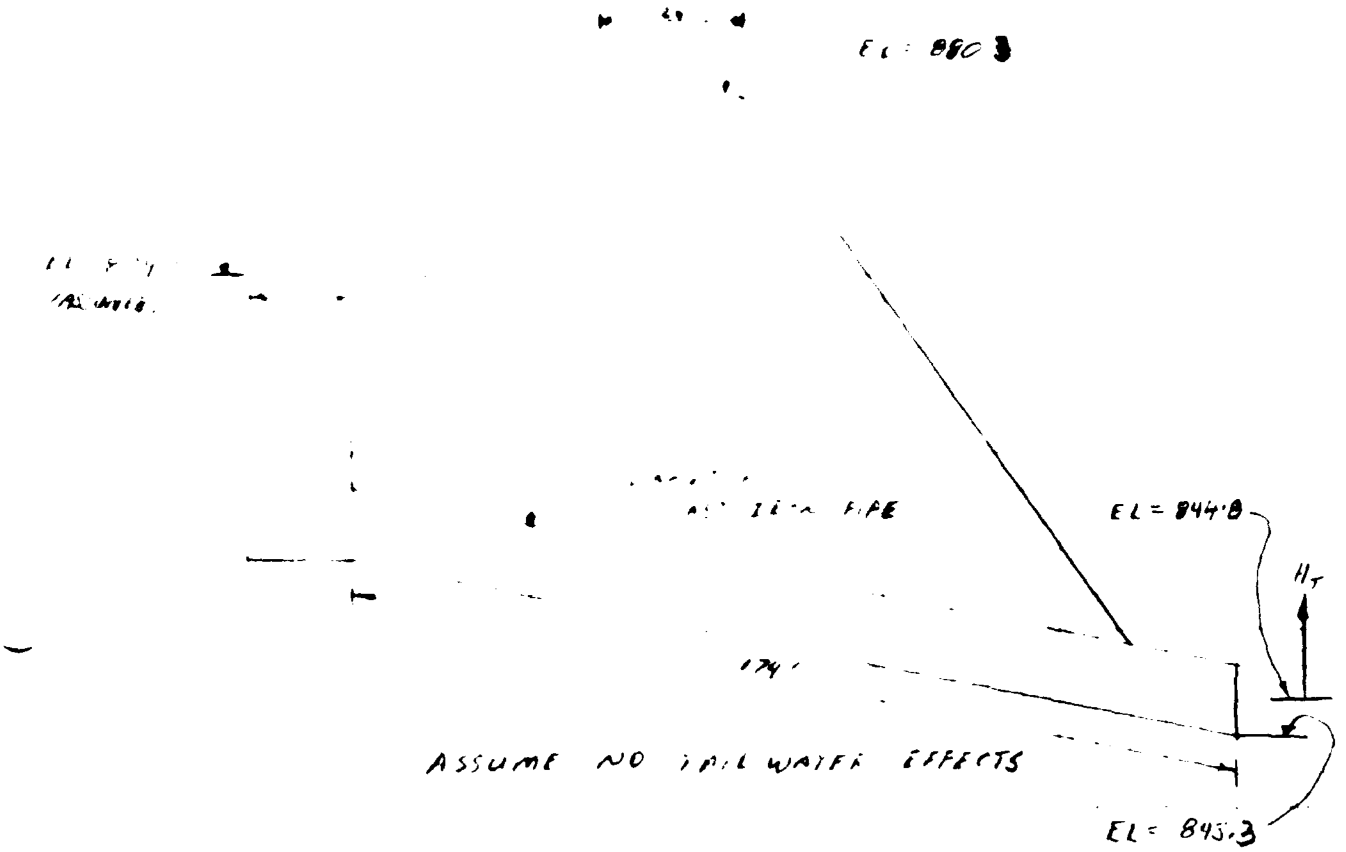

45.5
80'
45.5'
640'
50'
200'
Y_1
3.3'
WIDTH = 26'
H_3
ELEV. = 880.3
Y_3
TOP OF DAM ELEV. = 879.8
EMERGENCY SPILLWAY
ELEV. = 877.0

Y_{c_1}	A_{c_1}	T_{c_1}	$V_{c_1} = 5.67\sqrt{\frac{A_{c_1}}{T_{c_1}}}$	$\frac{V_{c_1}^2}{2g}$	U.S. W.S. = $Y_{c_1} + \frac{V_{c_1}^2}{2g} + 877.0$	$Q_1 = A_1 V_{c_1}$	$Y_{c_2} = \frac{2}{3}$ (U.S.W.S. − 879.8)	A_{c_2}	T_{c_2}	$V_{c_2} = 5.67\sqrt{\frac{A_{c_2}}{T_{c_2}}}$	$Q_{c_2} = A_{c_2} \cdot V_{c_2}$	C_3	L_3	H_3	$Q_3 = C_3 L_3 H_3^{3/2}$	$Q_t = Q_{c_1} + Q_{c_2} + Q_3$
0.5	43.4	93.8	3.86	0.23	877.73	167.5										168
1.0	93.8	107.6	5.29	0.44	878.44	496.2										496
1.5	157.0	121.4	6.32	0.62	879.12	954.3										954
2.0	215.2	135.2	7.15	0.79	879.79	1538.6										1539
2.4	271.4	146.2	7.73	0.93	880.33	2097.9	0.35	76.1	235.0	3.23	245.8	2.63	640	0.03	8.75	2352
2.5	286.2	148.9	7.86	0.96	880.46	2249.5	0.44	97.7	244.0	3.59	350.7	2.63	640	0.16	107.7	2708
3.0	364.0	162.7	8.48	1.12	881.12	3086.7	0.88	207.5	250.0	5.17	1072.8	2.63	640	0.82	1249.8	5409
4.0	533.9	171.0	10.02	1.56	882.56	5349.7	1.84	447.5	250.0	7.59	3396.5	2.63	640	2.26	5718.7	14465
5.0	704.9	171	11.51	2.06	884.16	8113.4	2.84	697.5	250.0	9.47	6605.3	2.63	640	3.76	12272	26990

DAM SAFETY INSPECTION - MISSOURI SHEET NO. 1 OF

ELMWOOD CITY LAKE DAM JOB NO. 1240-001-1

SPILLWAY RATING CURVE BY KLB DATE 8-13-7



ASSUME NO TAILWATER EFFECTS

W.L AT 874.5

a) WEIR FLOW ASSUME $C = 3.0$

$L = \pi D = \pi \cdot 5 = 15.73$

$Q = C L H^{3/2}$

$H = 874.5 - 874 = 0.5$

$Q = 3.3 \times 15.73 \times 0.5^{3/2} = 17$ CFS

b) PRESSURE FLOW

ASSUME $K_e = 0.5$, $f = 0.015$

$$H_T = \left(1 + K_e + f \frac{L}{D}\right) \frac{V^2}{2g}$$

ENGINEERING CONSULTANTS, INC.

DAM SAFETY INSPECTION - MISSOURI SHEET NO. 2 OF

ELMWOOD CITY LAKE DAM JOB NO. 1240-001-1

SPILLWAY RATING CURVE BY KLB ✓MAS DATE 8-13

$$H_T = \left(1 + 0.5 + 0.015 \frac{174}{3}\right) \frac{V^2}{2g}$$

$$H_T = 2.37 \frac{V^2}{2g}$$

$$V = \sqrt{\frac{2g\ H_T}{2.37}} = \sqrt{\frac{64.4}{2.37} HT} = 5.21 \sqrt{H_T}$$

$$Q = V.A = 5.21 \sqrt{H_T} \times \pi \frac{D^2}{4} = 5.21 \times \pi \times 3^2/4 \sqrt{H_T}$$

$$Q = 36.88 \sqrt{H_T}$$

$$H_T = 874.5 - 844.8 = 29.7$$

$Q = 36.88 \sqrt{29.7}$

Q = 201 CFS > 17 CFS.

∴ AT WL = 874.5, WEIR FLOW CONTROLLS

AND Q = 17 CFS.

AT W.L. 875

a) WEIR FLOW $H = 875 - 874 = 1$

$Q = CLH^{3/2} = 3 \times 15.73 \times 1^{3/2} = 47$ CFS

b) PRESSURE FLOW $H_T = 875 - 844.8 = 30.20$

$Q = 36.88 \sqrt{H_T} = 36.88 \sqrt{30.2} = 203$ CFS.

∴ AT WL. = 875 WEIR FLOW CONTROLS

AND Q = 47 CFS.

DAM SAFETY INSPECTION - MISSOURI SHEET NO. 3 OF

ELMWOOD CITY LAKE DAM JOB NO. 1240-001

SPILLWAY RATING CURVE BY KLB DATE 8-13-

✓ DAS

W.L. = 876

a) WEIR FLOW $H = 876 - 874 = 2$

$Q = CLH^{3/2} = 3.0 \times 15.73 \times 2^{3/2} =$

$Q = 133.$ CFS.

b) PRESSURE FLOW $H_T = 876 - 844.8 = 31.2$

$Q = 36.88\sqrt{H_T} = 36.88\sqrt{31.2} = 206$ CFS > 133 CFS

∴ AT WL 876 WEIR FLOW CONTROLS

AND $Q = \underline{\underline{133}}$ CFS.

WL = 877

a) WEIR FLOW $H = 877 - 874 = 3$

$Q = CLH^{3/2} = 3 \times 15.73 \times 3^{3/2}$

$Q = 245$ CFS

b) PRESSURE FLOW $H_T = 877 - 844.8 = 32.2$

$Q = 36.88\sqrt{H_T} = 36.88\sqrt{32.2} = 209$ CFS < 245 CFS

∴ AT WL = 877 PRESSURE FLOW CONTROLS

AND $Q = \underline{\underline{209}}$ CFS.

ALSO FOR ALL ELEVATIONS ABOVE 877 THE EQUATION

$Q = 36.88\sqrt{H_T}$ will HOLD.

PRC ENGINEERING CONSULTANTS, INC.

Dam Safety Inspection - Missouri SHEET NO. 4 OF

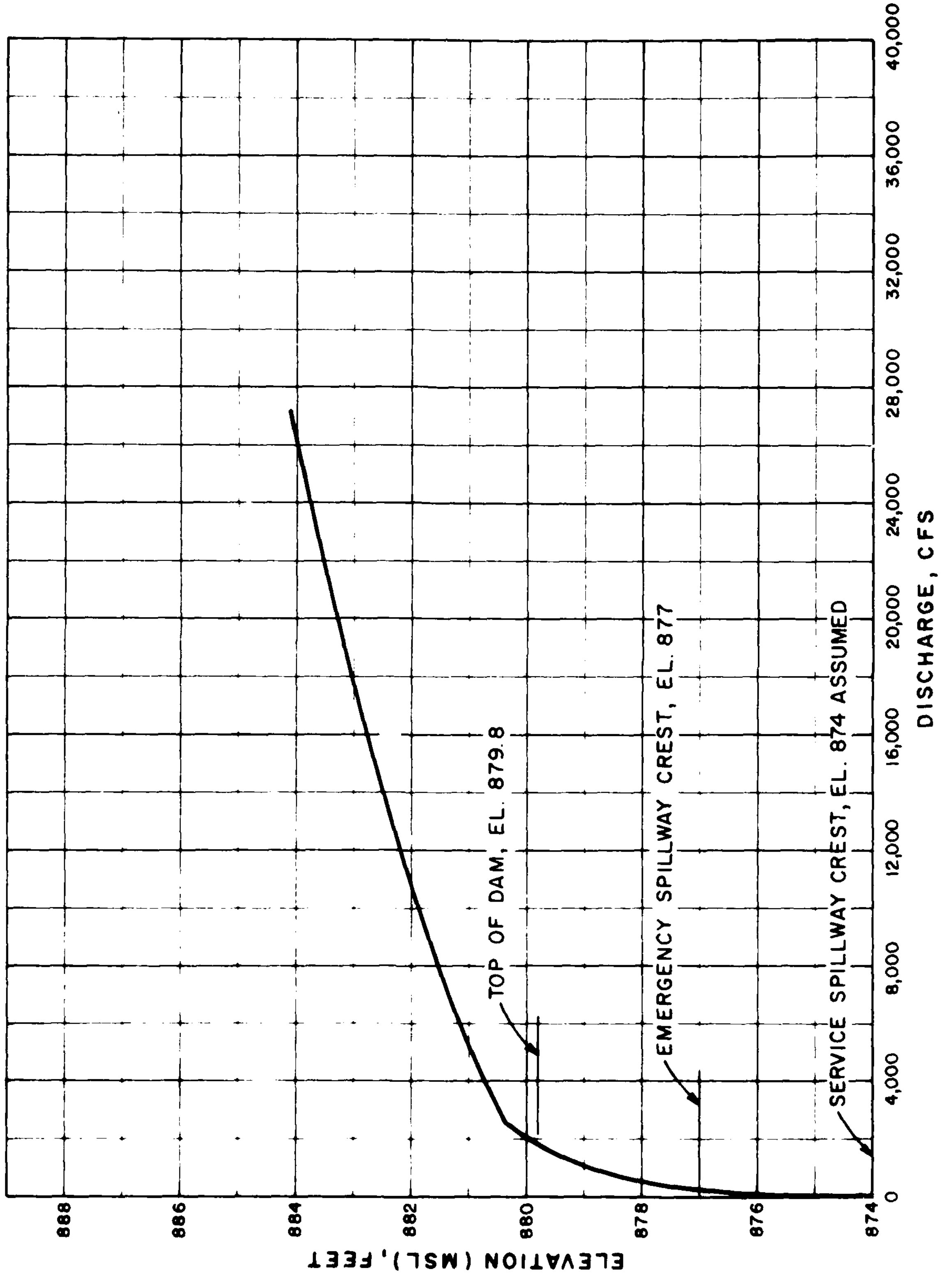
Elmwood City Lake Dam JOB NO. 1206

Combined Spillway And Overtop Rating Curve BY RRW DATE 9-18

Reservoir Surface Elevation	Head on Principle Spillway, Ht.	Principle Spillway Discharge $Q=36.88\sqrt{H_t}$	Emergency Spillway Discharge	Overtop Discharge	Combined Discharge
874	—	0	—	—	0
874.5	29.7	17*	—	—	17
875	30.2	47*	—	—	47
876	31.2	133*	—	—	133
877	32.2	209	—	—	209
877.73	32.93	212	168	—	380
878.44	33.64	214	496.	—	710
879.12	34.32	216	954	—	1170
879.79	34.99	218	1539	—	1757
880.33	35.53	220	2097.9	254.6	2573
880.46	35.66	220.	2249.5	458.4	2928
881.12	36.32	222.	3086.7	2322.6	5631
882.56	37.76	227	5349.7	9115.2	14692
884.16	39.36	231	8113.4	18877.3	27222

* Weir flow controls

PLATE 2, APPENDIX B



ELMWOOD CITY LAKE DAM (MO. 10240)
SPILLWAY AND OVERTOP RATING CURVE

ECI-4 **ENGINEERING CONSULTANTS, INC.**

DAM SAFETY INSPECTION — SHEET NO. 1 OF

ELMWOOD CITY LAKE Dam ID# 10240 — JOB NO. 1240

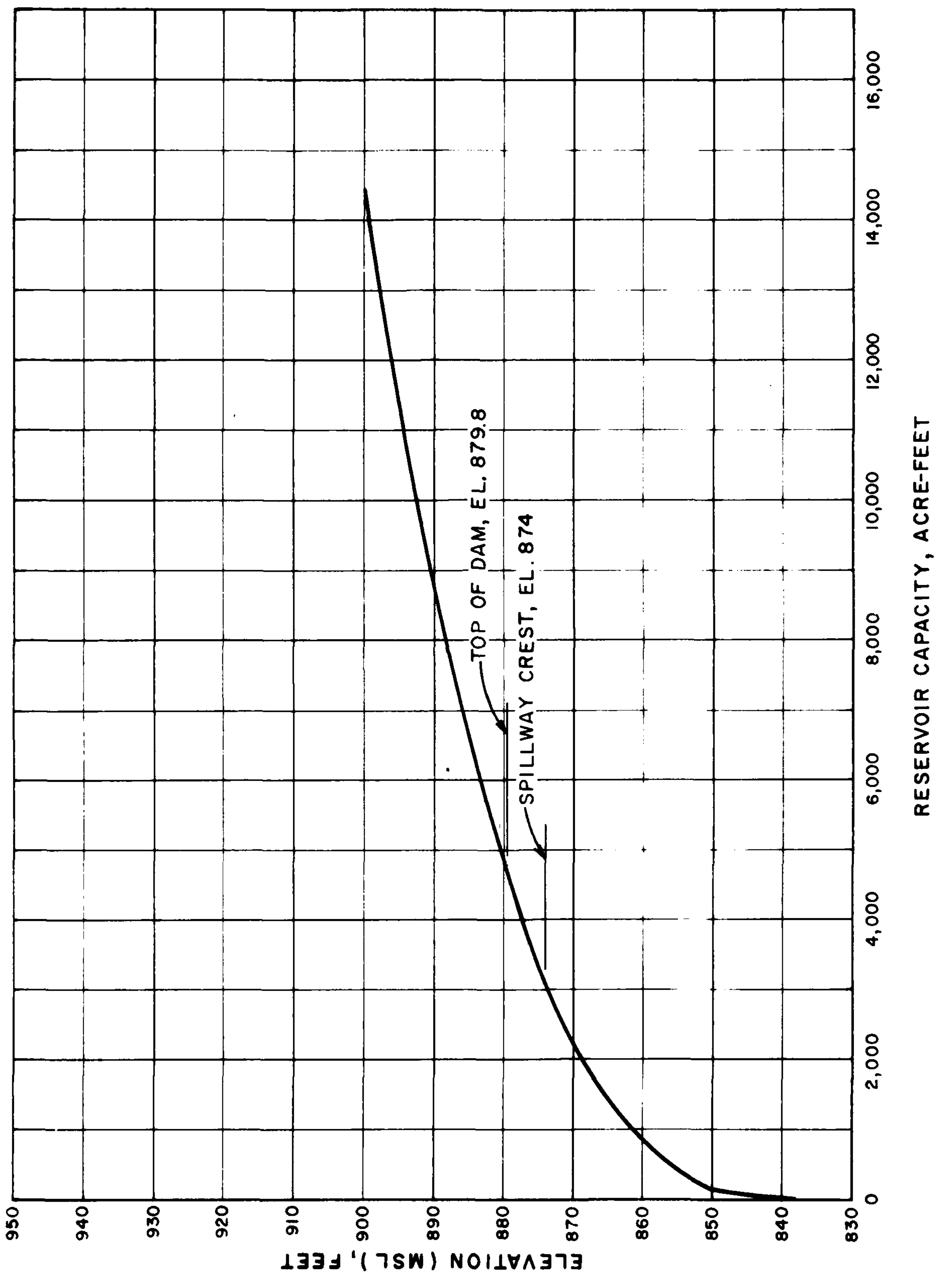
RESERVOIR AREA CAPACITY — BY RHK / KLB — DATE 7-12-79

ELMWOOD CITY LAKE DAM

RESERVOIR AREA CAPACITY

ELEV. MSL (ft)	RESERVOIR Surface Area (Acres)	INCREMENTAL Volume (AC-ft)	TOTAL Volume (AC-ft)	REMARKS
838	0	0	0	Est Streambed Elev. at Dam
840	5	3.3	3.3	
850	35	177.4	181	
860	100	647.2	828	
870	190	1426.11	2254	
874	250	877.3	3131	Service Spillway Crest
877	290	809.3	3940	Emergency Spillway Crest
879.8	330	867.4	4807	Top of Dam
880	338	668	4874	
890	478	4060	8934	
900	615	5450.6	14385	

PLATE 3, APPENDIX B



ELMWOOD CITY LAKE DAM (MO. 10240)
RESERVOIR CAPACITY CURVE

B-10

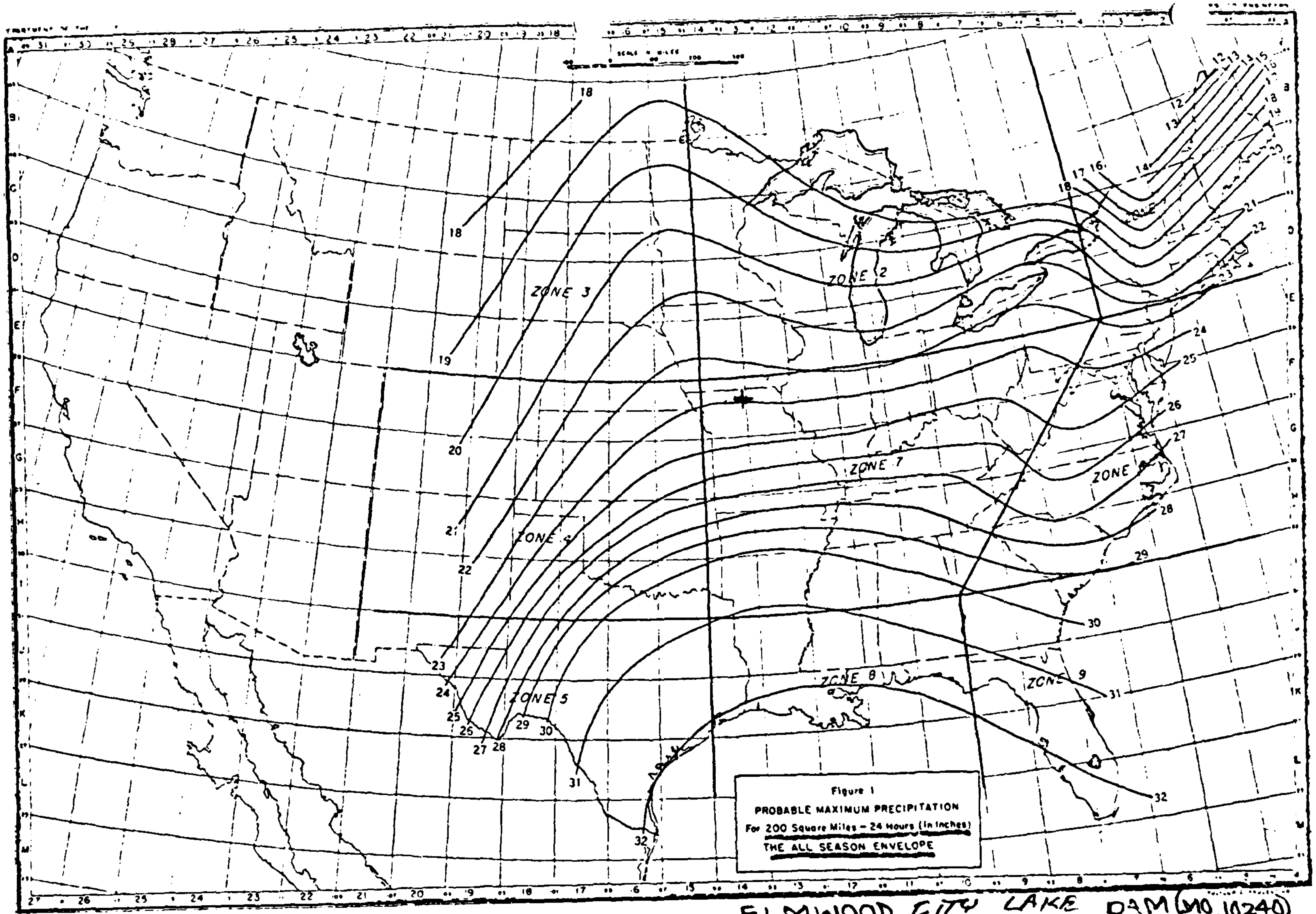

ZONE 2
ZONE 3
ZONE 4
ZONE 5
ZONE 6
ZONE 7
ZONE 8
ZONE 9
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
+

Figure 1
PROBABLE MAXIMUM PRECIPITATION
For 200 Square Miles – 24 Hours (In Inches)
THE ALL SEASON ENVELOPE

+ LOCATION OF
CENTROID OF WATERSHED

ELMWOOD CITY LAKE DAM (MO. 10240)
DETERMINATION OF PMP
INDEX RAINFALL.

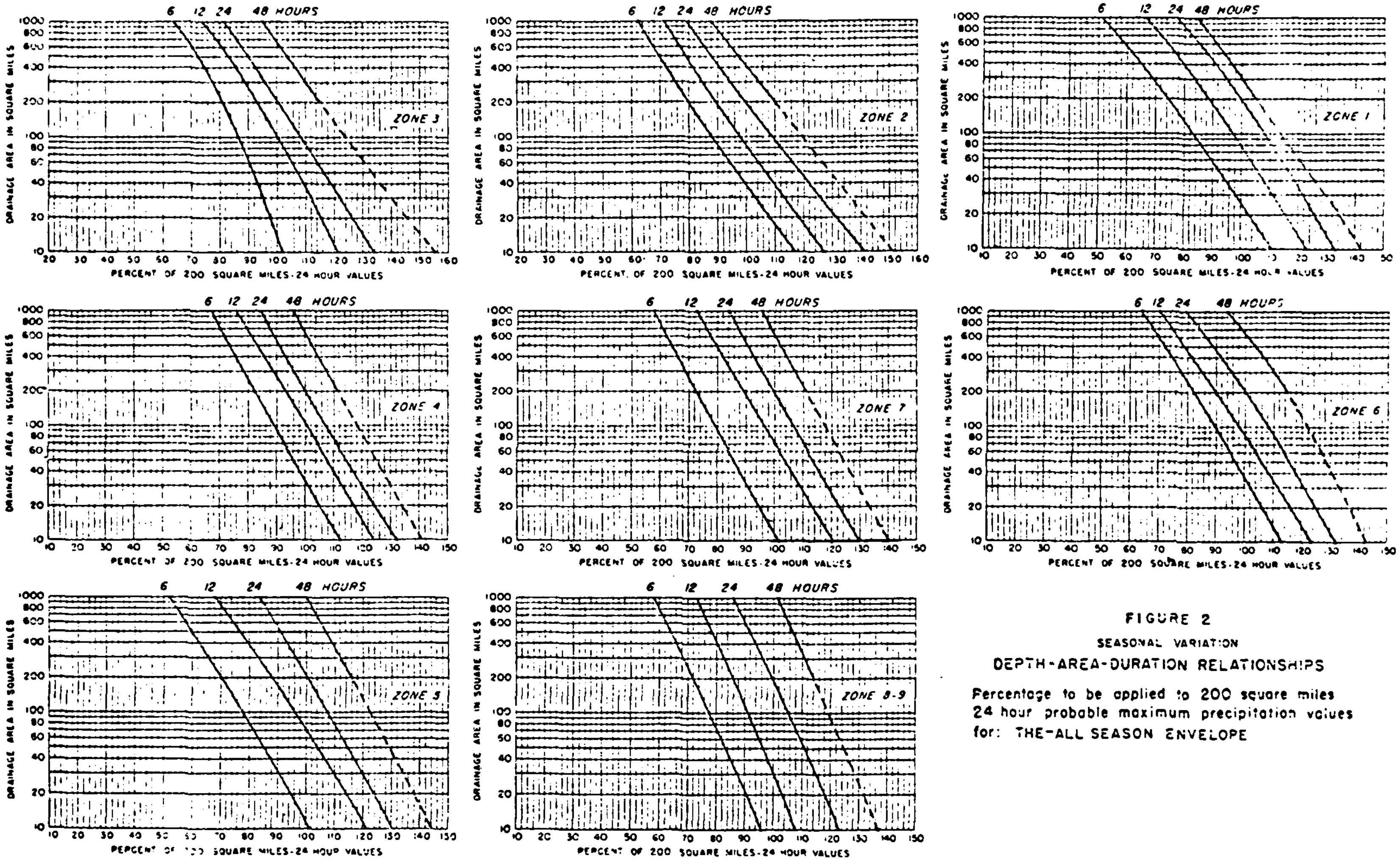


FIGURE 2

SEASONAL VARIATION

DEPTH-AREA-DURATION RELATIONSHIPS

Percentage to be applied to 200 square miles
24 hour probable maximum precipitation values
for: THE-ALL SEASON ENVELOPE

PRC ENGINEERING CONSULTANTS, INC.

DAM SAFETY INSPECTION – MISSOURI SHEET NO. 1 OF ____
MISSOURI DAM 10240 JOB NO. 1240-001
UNIT HYDROGRAPH PARAMETERS BY KLB DATE 8-7-

1. DRAINAGE AREA = 4100 AC. = 6.41 SQ. MI.

2. LENGTH OF STREAM = (8.9" × 2000'/5280) = 3.37 MI.

3. ELEVATION OF DRAINAGE DIVIDE ALONG THE LONGEST STREAM. = 1045 Ft

4. RESERVOIR ELEVATION AT SPILLWAY CREST = 873 Ft.

5. DIFFERENCE IN ELEVATION = ΔH = 172 Ft.

6. AVERAGE SLOPE OF STREAM = $\frac{\Delta H}{L} = \frac{172}{17800}$ = 0.96 %

7. TIME OF CONCENTRATION

a) BY KIRPICH FORMULA:

$$T_C = \left(\frac{11.9 \times L^3}{\Delta H}\right)^{0.385} = \left(\frac{11.9 \times 3.37^3}{172}\right)^{0.385}$$

T_C = 1.46 HR.

b) VELOCITY ESTIMATE:

AVERAGE SLOPE = 0.92 % ⇒ V = 2.0 FPS

$$T_c = \frac{8.9 \times 2000}{2 \times 3600} = 2.47 \text{ HR}$$

USE T_C = 1.46 HR

8. LAG TIME = $0.6 \times T_C = 0.6 \times 1.46$ = 0.88 HR = L_t

9. UNIT DURATION $D \le \frac{L_t}{4} = \frac{0.88}{4}$ 0.22 HR

USE D = 10 MIN = 0.167 HR

10. TIME TO PEAK, $T_P = \frac{D}{2} + L_t = 0.96$

11. PEAK DISCHARGE $q_p = \frac{484 \times A}{T_P} = \frac{484 \times 6.41}{0.96}$ = 3232 CFS.

PRC ENGINEERING CONSULTANTS, INC.

DAM SAFETY INSPECTION - MISSOURI SHEET NO. 1 OF
ELMWOOD CITY LAKE DAM (10240) JOB NO. 1240-001-1
SOIL GROUP AND CURVE NUMBER DETERMINATION BY KLB DATE 8-14-7

ELMWOOD CITY LAKE DAM

HYDROLOGIC SOIL GROUP AND CURVE NUMBER

1. WATERSHED SOILS CONSIST PRIMARILY OF GROUP B, C AND D SOILS. ASSUME GROUP C FOR HYDROLOGIC PURPOSES. OVER THE ENTIRE WATERSHED.

2. THIS WATERSHED IS PRIMARILY PASTURE AND MEADOWS WITH ABOUT 10% FOREST COVER. ASSUME THE HYDROLOGIC CONDITION OF THIS WATERSHED IS "FAIR"

THUS:
CN = 79 (PASTURE) - 40%
CN = 71 (Meadow) - 40%
CN = 73 (WOODS) - 10%

WEIGHTED AVERAGE CN = 79X·4+71X·4X73X·1

CN = 77 WITH AMC II

⇒ CN = 89 WITH AMC III

DAM SAFETY INSPECTION - MISSOURI SHEET NO. 1 OF

ELMWOOD CITY LAKE DAM (10240) JOB NO. 1240-001-1

100 YEAR FLOOD BY REGRESSION EQUATION BY KLB DATE 8-7-7

ELMWOOD CITY LAKE DAM (10240)

100 YEAR FLOOD BY REGRESSION EQUATION

REGRESSION EQUATION FOR THE 100 YEAR FLOOD FOR MISSOURI:

$$Q_{100} = 85.1\, A^{0.934 A^{-0.02}}\, S^{0.576}$$

WHERE:

A = DRAINAGE AREA IN SQ. MI.

S = MAIN CHANNEL SLOPE Ft/mi
(AVG. SLOPE BETWEEN 0.1L AND 0.85L)

FOR MISSOURI DAM 10240

$A = 6.41$ SQ. MI.

$S = 28.85$ Ft/mi.

$$Q_{100} = 85.1\,(6.41)^{0.934\,(6.41)^{-0.02}}\,(28.85)^{0.576}$$

Q_{100} = 3141 CFS

HEC1DB INPUT DATA

```
********************************
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION      JULY 1978
  LAST MODIFICATION  26 FEB 79
********************************
     1          A1                  DAM SAFETY INSPECTION - MISSOURI
     2          A2                    ELMWOOD CITY LAKE DAM (10240)
     3          A3                     PMF AND 50 PERCENT PMF
     4          B     300       0      10       0       0       0       0       0       0       0
     5          B1      5
     6          J       1       2       1
     7          J1      1      .5
     8          K       0   10240
     9          K1  INPUT PRECIPITATION VALUES, RATIOS AND UNIT HYDROGRAPH PARAMETERS
    10          M       1       2    6.41            6.41     1.0
    11          P            23.9    100.    120.    130.
    12          T                                                      -1    -.09
    13          J2            .88
    14          X       0       0       1              2.
    15          K       1   10240
    16          K1  ROUTE HYDROGRAPH THROUGH ELMWOOD CITY LAKE DAM
    17          Y                                1       1
    18          Y1                  7                                -874.     -1
    19          Y4    874   874.5     875     876     877  877.73  878.44  879.12  879.79  880.33
    20          Y4880.46  881.12  882.56  884.16
    21          Y5      0      17      47     133     209     380     710    1170    1757    2573
    22          Y5   3928    5631   14692   27222
    23          $S      0       3     171     823    2254    3131    3940    4807    8934   14385
    24          $E    838     840     850     860     870     874     877   879.8     890     900
    25          $$   874.
    26          $D  879.8
    27          K      99
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PREVIEW OF SEQUENCE OF STREAM NETWORK CALCULATIONS

          RUNOFF HYDROGRAPH AT          10240
          ROUTE HYDROGRAPH TO           10240
          END OF NETWORK
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INFLOW PMF AND ONE-HALF PMF HYDROGRAPHS

```
           0.        0.        0.        0.        0.        0.        0.        0.        0.        0.
           0.        0.        0.        0.        0.        0.        0.        0.        0.        0.

                             PEAK    6-HOUR   24-HOUR   72-HOUR   TOTAL VOLUME
                     CFS    15763.    7827.    2552.     1225.       367567.
                     CMS      446.     222.      72.       35.        10408.
                  INCHES              11.36    14.81     14.82         14.82
                      MM             288.49   376.29    376.36        376.36
                   AC-FT              3381.    5062.     5063.         5063.
             THOUS CU M               4787.    6244.     6245.         6245.


      **********          **********          **********          **********          **********

                                        HYDROGRAPH ROUTING

             ROUTE HYDROGRAPH THROUGH ELMWOOD CITY LAKE DAM

                         ISTAQ   ICOMP   IECON   ITAPE    JPLT    JPRT   INAME  ISTAGE   IAUTO
                         10240       1       0       0       0       0       0       0       0
                                               ROUTING DATA
                 QLOSS   CLOSS     AVG    IRES   ISAME    IOPT    IPMP            LSTR
                   0.0   0.000    0.00       1       1       0       0               0

                         NSTPS   NSTDL     LAG   AMSKK       X     TSK    STORA  ISPRAT
                             0       0       0   0.000   0.000   0.000    -874.      -1

   STAGE      874.00     874.50     875.00     876.00     877.00     877.73     878.44     879.12     879.79     880.33
              880.46     881.12     882.56     884.16

    FLOW        0.00      17.00      47.00     133.00     209.00     380.00     713.00    1170.00    1757.00    2573.00
             2928.00    5631.00   14692.00   27222.00

   CAPACITY=       0.         3.       191.       528.      2254.      3131.      3940.      4807.      8934.     14385.

  ELEVATION=     838.       840.       850.       860.       870.       874.       877.       880.       890.       900.

                     CREL   SPWID   COQW    EXPW   ELEVL    COQL   CAREA    EXPL
                    874.0     0.0    0.0     0.0     0.0     0.0     0.0     0.0

                                           DAM DATA
                                  TOPEL    COQD    EXPD  DAMWID
                                  879.8     0.0     0.0      0.

                                  STATION  10240, PLAN 1, RATIO 1

                                END-OF-PERIOD HYDROGRAPH ORDINATES

                                            OUTFLOW
             0.        0.        0.        0.        0.        0.        0.        0.        0.        0.
             0.        0.        0.        0.        0.        0.        0.        0.        1.        1.
             1.        1.        1.        1.        2.        2.        2.        3.        3.        4.
             4.        5.        5.        6.        6.        7.        7.        8.        9.       10.
            11.       13.       16.       20.       25.       31.       38.       45.       54.       65.
            76.       87.       99.      111.      122.      134.      145.      156.      167.      177.
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AD-A104 616 CONSOER TOWNSEND AND ASSOCIATES LTD ST LOUIS MO F/G 13/13
NATIONAL DAM SAFETY PROGRAM. ELMWOOD CITY LAKE DAM (MO 10240), --ETC(U)
DEC 79 W G SHIFRIN DACW43-79-C-00075

UNCLASSIFIED NL

2 OF 2
AD
A104616

END
DATE
FILMED
10-81
DTIC

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   27760.   24691.   21809.   19693.   18060.   16650.   15407.   14389.   13453.   12471.
   11317.    9912.    8390.    6903.    5557.    4426.    3858.    2927.    2447.    2074.
    1786.    1571.    1421.    1310.    1227.    1155.    1117.    1081.    1054.    1035.
    1020.    1008.     997.     993.     989.     997.     987.     987.     987.     987.
     987.     987.     987.     987.     976.     945.     880.     777.     633.     520.
     408.     307.     223.     172.     130.      98.      73.      55.      41.      31.
      23.      17.      13.       9.       7.       5.       3.       2.       1.       1.
       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.

                          PEAK    6-HOUR   24-HOUR   72-HOUR   TOTAL VOLUME
                 CFS    31527.    15653.     5104.     2450.       735134.
                 CMS      893.      443.      145.       69.        20817.
              INCHES               22.72     29.63     29.63         29.63
                  MM              576.99    752.55    752.72        752.72
               AC-FT                7762.    10124.    10126.        10126.
           THOUS CU M               9574.    12487.    12490.        12490.


                        HYDROGRAPH AT STA 10240 FOR PLAN 1, RTIO 2
       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
       0.       1.       3.       6.      10.      17.      24.      32.      41.      50.
      59.      68.      77.      85.      94.     102.     109.     117.     124.     130.
     137.     143.     149.     155.     160.     165.     179.     210.     272.     370.
     491.     521.     750.     868.     959.    1053.    1123.    1183.    1234.    1277.
    1315.    1347.    1375.    1399.    1420.    1439.    1455.    1470.    1482.    1494.
    1504.    1514.    1522.    1529.    1536.    1542.    1549.    1553.    1558.    1562.
    1546.    1573.    1607.    1712.    1925.    2263.    2669.    3087.    3487.    3854.
    4179.    4472.    4738.    4977.    5197.    5410.    5635.    5986.    6144.    6391.
    6605.    6817.    7155.    8090.    9732.   12000.   14292.   15573.   15763.   15089.
   13896.   12345.   10905.    9846.    9030.    8325.    7704.    7195.    6727.    6236.
    5658.    4955.    4195.    3450.    2778.    2213.    1779.    1463.    1223.    1037.
     893.     786.     711.     655.     614.     582.     558.     541.     527.     517.
     510.     504.     501.     496.     494.     473.     493.     493.     493.     493.
     493.     473.     493.     493.     488.     472.     440.     399.     327.     263.
     204.     153.     114.      86.      65.      49.      37.      28.      21.      15.
      12.       9.       6.       5.       3.       2.       2.       1.       1.       0.
       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
```

```
1.01  19.20   116   .04   .04   .00   4426.     1.02  20.20   266  0.00  0.00  0.00      0.
1.01  19.30   117   .04   .04   .00   3558.     1.02  20.30   267  0.00  0.00  0.00      0.
1.01  19.40   118   .04   .04   .00   2927.     1.02  20.40   268  0.00  0.00  0.00      0.
1.01  19.50   119   .04   .04   .00   2447.     1.02  20.50   269  0.00  0.00  0.00      0.
1.01  20.00   120   .04   .04   .00   2074.     1.02  21.00   270  0.00  0.00  0.00      0.
1.01  20.10   121   .04   .04   .00   1786.     1.02  21.10   271  0.00  0.00  0.00      0.
1.01  20.20   122   .04   .04   .00   1571.     1.02  21.20   272  0.00  0.00  0.00      0.
1.01  20.30   123   .04   .04   .00   1421.     1.02  21.30   273  0.00  0.00  0.00      0.
1.01  20.40   124   .04   .04   .00   1310.     1.02  21.40   274  0.00  0.00  0.00      0.
1.01  20.50   125   .04   .04   .00   1227.     1.02  21.50   275  0.00  0.00  0.00      0.
1.01  21.00   126   .04   .04   .00   1165.     1.02  22.00   276  0.00  0.00  0.00      0.
1.01  21.10   127   .04   .04   .00   1117.     1.02  22.10   277  0.00  0.00  0.00      0.
1.01  21.20   128   .04   .04   .00   1081.     1.02  22.20   278  0.00  0.00  0.00      0.
1.01  21.30   129   .04   .04   .00   1054.     1.02  22.30   279  0.00  0.00  0.00      0.
1.01  21.40   130   .04   .04   .00   1035.     1.02  22.40   280  0.00  0.00  0.00      0.
1.01  21.50   131   .04   .04   .00   1020.     1.02  22.50   281  0.00  0.00  0.00      0.
1.01  22.00   132   .04   .04   .00   1008.     1.02  23.00   282  0.00  0.00  0.00      0.
1.01  22.10   133   .04   .04   .00    999.     1.02  23.10   283  0.00  0.00  0.00      0.
1.01  22.20   134   .04   .04   .00    993.     1.02  23.20   284  0.00  0.00  0.00      0.
1.01  22.30   135   .04   .04   .00    989.     1.02  23.30   285  0.00  0.00  0.00      0.
1.01  22.40   136   .04   .04   .00    987.     1.02  23.40   286  0.00  0.00  0.00      0.
1.01  22.50   137   .04   .04   .00    987.     1.02  23.50   287  0.00  0.00  0.00      0.
1.01  23.00   138   .04   .04   .00    987.     1.03   0.00   288  0.00  0.00  0.00      0.
1.01  23.10   139   .04   .04   .00    987.     1.03    .10   289  0.00  0.00  0.00      0.
1.01  23.20   140   .04   .04   .00    987.     1.03    .20   290  0.00  0.00  0.00      0.
1.01  23.30   141   .04   .04   .00    987.     1.03    .30   291  0.00  0.00  0.00      0.
1.01  23.40   142   .04   .04   .00    987.     1.03    .40   292  0.00  0.00  0.00      0.
1.01  23.50   143   .04   .04   .00    987.     1.03    .50   293  0.00  0.00  0.00      0.
1.02   0.00   144   .04   .04   .00    987.     1.03   1.00   294  0.00  0.00  0.00      0.
1.02    .10   145  0.00  0.00  0.00    976.     1.03   1.10   295  0.00  0.00  0.00      0.
1.02    .20   146  0.00  0.00  0.00    945.     1.03   1.20   296  0.00  0.00  0.00      0.
1.02    .30   147  0.00  0.00  0.00    880.     1.03   1.30   297  0.00  0.00  0.00      0.
1.02    .40   148  0.00  0.00  0.00    777.     1.03   1.40   298  0.00  0.00  0.00      0.
1.02    .50   149  0.00  0.00  0.00    653.     1.03   1.50   299  0.00  0.00  0.00      0.
1.02   1.00   150  0.00  0.00  0.00    526.     1.03   2.00   300  0.00  0.00  0.00      0.

                                                              SUM  31.07 29.63  1.44   735137.
                                                                 ( 789.)( 753.)(  36.)(20816.76)

                        PEAK     6-HOUR    24-HOUR    72-HOUR   TOTAL VOLUME
              CFS      31527.    15653.      5104.      2450.      735134.
              CMS        893.      443.       145.        69.       20817.
           INCHES                 22.72      29.63      29.63        29.63
               MM                576.99     752.56     752.72       752.72
            AC-FT                 7762.     10124.     10126.       10126.
      THOUS CU M                  9574.     12487.     12490.       12490.


                        HYDROGRAPH AT STA 10240 FOR PLAN 1, RTIO 1
        0.        0.        0.        0.        0.        0.        0.        0.        0.        0.
        1.        2.        6.       12.       21.       33.       48.       64.       82.      100.
      118.      136.      154.      171.      187.      203.      219.      233.      247.      261.
      270.      286.      298.      309.      321.      330.      357.      421.      544.      739.
[illegible]    1243.     1499.     1736.     1939.     2108.     2245.     2365.     2468.     2555.
     2629.     2694.     2750.     2798.     2840.     2878.     2914.     2939.     2965.     2988.
[illegible]    3027.     3049.     3059.     3072.     3084.     3095.     3106.     3115.     3120.
[illegible]    3148.     3214.     3624.     3849.     4525.     5338.     6178.     6873.     7707.
[illegible]    8965.     9477.     9954.    10393.    10820.    11272.    11778.    12288.    12782.
    13209.    13654.    14303.    16180.    19963.    24008.    28885.    31146.    31587.    38179.
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1.01   9.20    56   .13   .12   .01    2878.      1.02  10.20   206  0.00  0.00  0.00     0.
1.01   9.30    57   .13   .12   .01    2910.      1.02  10.30   207  0.00  0.00  0.00     0.
1.01   9.40    58   .13   .12   .01    2939.      1.02  10.40   208  0.00  0.00  0.00     0.
1.01   9.50    59   .13   .12   .01    2965.      1.02  10.50   209  0.00  0.00  0.00     0.
1.01  10.00    60   .13   .12   .01    2988.      1.02  11.00   210  0.00  0.00  0.00     0.
1.01  10.10    61   .13   .13   .01    3009.      1.02  11.10   211  0.00  0.00  0.00     0.
1.01  10.20    62   .13   .13   .01    3027.      1.02  11.20   212  0.00  0.00  0.00     0.
1.01  10.30    63   .13   .13   .01    3044.      1.02  11.30   213  0.00  0.00  0.00     0.
1.01  10.40    64   .13   .13   .01    3059.      1.02  11.40   214  0.00  0.00  0.00     0.
1.01  10.50    65   .13   .13   .01    3072.      1.02  11.50   215  0.00  0.00  0.00     0.
1.01  11.00    66   .13   .13   .01    3084.      1.02  12.00   216  0.00  0.00  0.00     0.
1.01  11.10    67   .13   .13   .01    3095.      1.02  12.10   217  0.00  0.00  0.00     0.
1.01  11.20    68   .13   .13   .01    3106.      1.02  12.20   218  0.00  0.00  0.00     0.
1.01  11.30    69   .13   .13   .01    3115.      1.02  12.30   219  0.00  0.00  0.00     0.
1.01  11.40    70   .13   .13   .00    3124.      1.02  12.40   220  0.00  0.00  0.00     0.
1.01  11.50    71   .13   .13   .00    3132.      1.02  12.50   221  0.00  0.00  0.00     0.
1.01  12.00    72   .13   .13   .00    3140.      1.02  13.00   222  0.00  0.00  0.00     0.
1.01  12.10    73   .40   .39   .01    3214.      1.02  13.10   223  0.00  0.00  0.00     0.
1.01  12.20    74   .40   .39   .01    3424.      1.02  13.20   224  0.00  0.00  0.00     0.
1.01  12.30    75   .40   .39   .01    3849.      1.02  13.30   225  0.00  0.00  0.00     0.
1.01  12.40    76   .40   .39   .01    4525.      1.02  13.40   226  0.00  0.00  0.00     0.
1.01  12.50    77   .40   .39   .01    5339.      1.02  13.50   227  0.00  0.00  0.00     0.
1.01  13.00    78   .40   .39   .01    6175.      1.02  14.00   228  0.00  0.00  0.00     0.
1.01  13.10    79   .48   .47   .01    6973.      1.02  14.10   229  0.00  0.00  0.00     0.
1.01  13.20    80   .48   .47   .01    7707.      1.02  14.20   230  0.00  0.00  0.00     0.
1.01  13.30    81   .48   .47   .01    8353.      1.02  14.30   231  0.00  0.00  0.00     0.
1.01  13.40    82   .48   .47   .01    8943.      1.02  14.40   232  0.00  0.00  0.00     0.
1.01  13.50    83   .48   .47   .01    9477.      1.02  14.50   233  0.00  0.00  0.00     0.
1.01  14.00    84   .48   .47   .01    9954.      1.02  15.00   234  0.00  0.00  0.00     0.
1.01  14.10    85   .60   .59   .01   10393.      1.02  15.10   235  0.00  0.00  0.00     0.
1.01  14.20    86   .60   .59   .01   10827.      1.02  15.20   236  0.00  0.00  0.00     0.
1.01  14.30    87   .60   .59   .01   11272.      1.02  15.30   237  0.00  0.00  0.00     0.
1.01  14.40    88   .60   .59   .00   11772.      1.02  15.40   238  0.00  0.00  0.00     0.
1.01  14.50    89   .60   .59   .00   12285.      1.02  15.50   239  0.00  0.00  0.00     0.
1.01  15.00    90   .60   .59   .00   12782.      1.02  16.00   240  0.00  0.00  0.00     0.
1.01  15.10    91   .54   .54   .00   13209.      1.02  16.10   241  0.00  0.00  0.00     0.
1.01  15.20    92   .91   .90   .01   13634.      1.02  16.20   242  0.00  0.00  0.00     0.
1.01  15.30    93  1.63  1.63   .01   14309.      1.02  16.30   243  0.00  0.00  0.00     0.
1.01  15.40    94  4.09  4.07   .01   16180.      1.02  16.40   244  0.00  0.00  0.00     0.
1.01  15.50    95  1.18  1.18   .00   19463.      1.02  16.50   245  0.00  0.00  0.00     0.
1.01  16.00    96   .73   .72   .00   24000.      1.02  17.00   246  0.00  0.00  0.00     0.
1.01  16.10    97   .56   .56   .00   28585.      1.02  17.10   247  0.00  0.00  0.00     0.
1.01  16.20    98   .56   .55   .00   31146.      1.02  17.20   248  0.00  0.00  0.00     0.
1.01  16.30    99   .56   .56   .00   31527.      1.02  17.30   249  0.00  0.00  0.00     0.
1.01  16.40   100   .56   .56   .00   30179.      1.02  17.40   250  0.00  0.00  0.00     0.
1.01  16.50   101   .56   .55   .00   27760.      1.02  17.50   251  0.00  0.00  0.00     0.
1.01  17.00   102   .55   .56   .00   24691.      1.02  18.00   252  0.00  0.00  0.00     0.
1.01  17.10   103   .44   .44   .00   21809.      1.02  18.10   253  0.00  0.00  0.00     0.
1.01  17.20   104   .44   .44   .00   19693.      1.02  18.20   254  0.00  0.00  0.00     0.
1.01  17.30   105   .44   .44   .00   18060.      1.02  18.30   255  0.00  0.00  0.00     0.
1.01  17.40   106   .44   .44   .00   16650.      1.02  18.40   256  0.00  0.00  0.00     0.
1.01  17.50   107   .44   .44   .00   15407.      1.02  18.50   257  0.00  0.00  0.00     0.
1.01  18.00   108   .44   .44   .00   14389.      1.02  19.00   258  0.00  0.00  0.00     0.
1.01  18.10   109   .04   .04   .00   13453.      1.02  19.10   259  0.00  0.00  0.00     0.
1.01  18.20   110   .04   .04   .00   12471.      1.02  19.20   260  0.00  0.00  0.00     0.
1.01  18.30   111   .04   .04   .00   11317.      1.02  19.30   261  0.00  0.00  0.00     0.
1.01  18.40   112   .04   .04   .00    9912.      1.02  19.40   262  0.00  0.00  0.00     0.
1.01  18.50   113   .04   .04   .00    8390.      1.02  19.50   263  0.00  0.00  0.00     0.
1.01  19.00   114   .04   .04   .00    6900.      1.02  20.00   264  0.00  0.00  0.00     0.
1.01  19.10   115   .04   .04   .00    5557.      1.02  20.10   265  0.00  0.00  0.00     0.
```

```
          64.       49.       37.       29.       23.       16.       11.       5.

                                              END-OF-PERIOD FLOW
MO.DA  HR.MN  PERIOD   RAIN   EXCS   LOSS     COMP Q       MO.DA  HR.MN  PERIOD   RAIN   EXCS   LOSS     COMP Q

 1.01    .10      1     .03   0.00    .03        0.         1.02   1.10    151    0.00   0.00   0.00       408.
 1.01    .20      2     .03   0.00    .03        0.         1.02   1.20    152    0.00   0.00   0.00       307.
 1.01    .30      3     .03   0.00    .03        0.         1.02   1.30    153    0.00   0.00   0.00       228.
 1.01    .40      4     .03   0.00    .03        0.         1.02   1.40    154    0.00   0.00   0.00       172.
 1.01    .50      5     .03   0.00    .03        0.         1.02   1.50    155    0.00   0.00   0.00       130.
 1.01   1.00      6     .03   0.00    .03        0.         1.02   2.00    156    0.00   0.00   0.00        98.
 1.01   1.10      7     .03   0.00    .03        0.         1.02   2.10    157    0.00   0.00   0.00        73.
 1.01   1.20      8     .03   0.00    .03        0.         1.02   2.20    158    0.00   0.00   0.00        55.
 1.01   1.30      9     .03   0.00    .03        0.         1.02   2.30    159    0.00   0.00   0.00        41.
 1.01   1.40     10     .03    .00    .03        0.         1.02   2.40    160    0.00   0.00   0.00        31.
 1.01   1.50     11     .03    .00    .03        1.         1.02   2.50    161    0.00   0.00   0.00        23.
 1.01   2.00     12     .03    .00    .02        2.         1.02   3.00    162    0.00   0.00   0.00        17.
 1.01   2.10     13     .03    .00    .02        6.         1.02   3.10    163    0.00   0.00   0.00        13.
 1.01   2.20     14     .03    .00    .02       12.         1.02   3.20    164    0.00   0.00   0.00         9.
 1.01   2.30     15     .03    .01    .02       21.         1.02   3.30    165    0.00   0.00   0.00         7.
 1.01   2.40     16     .03    .01    .02       33.         1.02   3.40    166    0.00   0.00   0.00         5.
 1.01   2.50     17     .03    .01    .02       46.         1.02   3.50    167    0.00   0.00   0.00         3.
 1.01   3.00     18     .03    .01    .02       64.         1.02   4.00    168    0.00   0.00   0.00         2.
 1.01   3.10     19     .03    .01    .02       82.         1.02   4.10    169    0.00   0.00   0.00         1.
 1.01   3.20     20     .03    .01    .02      100.         1.02   4.20    170    0.00   0.00   0.00         1.
 1.01   3.30     21     .03    .01    .02      118.         1.02   4.30    171    0.00   0.00   0.00         0.
 1.01   3.40     22     .03    .01    .02      136.         1.02   4.40    172    0.00   0.00   0.00         0.
 1.01   3.50     23     .03    .01    .02      154.         1.02   4.50    173    0.00   0.00   0.00         0.
 1.01   4.00     24     .03    .01    .02      171.         1.02   5.00    174    0.00   0.00   0.00         0.
 1.01   4.10     25     .03    .01    .02      187.         1.02   5.10    175    0.00   0.00   0.00         0.
 1.01   4.20     26     .03    .01    .01      203.         1.02   5.20    176    0.00   0.00   0.00         0.
 1.01   4.30     27     .03    .01    .01      219.         1.02   5.30    177    0.00   0.00   0.00         0.
 1.01   4.40     28     .03    .01    .01      233.         1.02   5.40    178    0.00   0.00   0.00         0.
 1.01   4.50     29     .03    .01    .01      247.         1.02   5.50    179    0.00   0.00   0.00         0.
 1.01   5.00     30     .03    .01    .01      261.         1.02   6.00    180    0.00   0.00   0.00         0.
 1.01   5.10     31     .03    .01    .01      274.         1.02   6.10    181    0.00   0.00   0.00         0.
 1.01   5.20     32     .03    .01    .01      286.         1.02   6.20    182    0.00   0.00   0.00         0.
 1.01   5.30     33     .03    .01    .01      298.         1.02   6.30    183    0.00   0.00   0.00         0.
 1.01   5.40     34     .03    .02    .01      309.         1.02   6.40    184    0.00   0.00   0.00         0.
 1.01   5.50     35     .03    .02    .01      320.         1.02   6.50    185    0.00   0.00   0.00         0.
 1.01   6.00     36     .03    .02    .01      330.         1.02   7.00    186    0.00   0.00   0.00         0.
 1.01   6.10     37     .13    .08    .05      357.         1.02   7.10    187    0.00   0.00   0.00         0.
 1.01   6.20     38     .13    .09    .04      421.         1.02   7.20    188    0.00   0.00   0.00         0.
 1.01   6.30     39     .13    .09    .04      544.         1.02   7.30    189    0.00   0.00   0.00         0.
 1.01   6.40     40     .13    .10    .03      739.         1.02   7.40    190    0.00   0.00   0.00         0.
 1.01   6.50     41     .13    .10    .03      981.         1.02   7.50    191    0.00   0.00   0.00         0.
 1.01   7.00     42     .13    .10    .03     1243.         1.02   8.00    192    0.00   0.00   0.00         0.
 1.01   7.10     43     .13    .11    .03     1499.         1.02   8.10    193    0.00   0.00   0.00         0.
 1.01   7.20     44     .13    .11    .02     1736.         1.02   8.20    194    0.00   0.00   0.00         0.
 1.01   7.30     45     .13    .11    .02     1939.         1.02   8.30    195    0.00   0.00   0.00         0.
 1.01   7.40     46     .13    .11    .02     2105.         1.02   8.40    196    0.00   0.00   0.00         0.
 1.01   7.50     47     .13    .11    .02     2245.         1.02   8.50    197    0.00   0.00   0.00         0.
 1.01   8.00     48     .13    .12    .02     2365.         1.02   9.00    198    0.00   0.00   0.00         0.
 1.01   8.10     49     .13    .12    .02     2468.         1.02   9.10    199    0.00   0.00   0.00         0.
 1.01   8.20     50     .13    .12    .01     2555.         1.02   9.20    200    0.00   0.00   0.00         0.
 1.01   8.30     51     .13    .12    .01     2629.         1.02   9.30    201    0.00   0.00   0.00         0.
 1.01   8.40     52     .13    .12    .01     2694.         1.02   9.40    202    0.00   0.00   0.00         0.
 1.01   8.50     53     .13    .12    .01     2750.         1.02   9.50    203    0.00   0.00   0.00         0.
 1.01   9.00     54     .13    .12    .01     2798.         1.02  10.00    204    0.00   0.00   0.00         0.
 1.01   9.10     55     .13    .12    .01     2840.         1.02  10.10    205    0.00   0.00   0.00         0.
```

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**********************************
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION       JULY 1978
  LAST MODIFICATION  26 FEB 79
**********************************

RUN  DATE* 79/11/28.
     TIME* 07.18.19.


                              DAM SAFETY INSPECTION - MISSOURI
                               ELMWOOD CITY LAKE DAM (10240)
                                PMF AND 50 PERCENT PMF

                                  JOB SPECIFICATION
          NQ      NHR     NMIN     IDAY      IHR     IMIN    METRC     IPLT     IPRT    NSTAN
         300        0       10        0        0        0        0        0        0        0
                                  JOPER      NWT    LROPT    TRACE
                                      5        0        0        0

                             MULTI-PLAN ANALYSES TO BE PERFORMED
                                 NPLAN= 1 NRTIO= 2 LRTIO= 1
          RTIOS=    1.00     .50


   *********          *********          *********          *********          *********

                                 SUB-AREA RUNOFF COMPUTATION

      INPUT PRECIPITATION VALUES, RATIOS AND UNIT HYDROGRAPH PARAMETERS

                      ISTAQ   ICOMP   IECON   ITAPE    JPLT    JPRT   INAME  ISTAGE   IAUTO
                      10240       0       0       0       0       0       0       0       0

                                       HYDROGRAPH DATA
          IHYDG    IUHG   TAREA    SNAP   TRSDA   TRSPC   RATIO   ISNOW   ISAME   LOCAL
              1       2    6.41    0.00    6.41    1.00   0.000       0       0       0

                                        PRECIP DATA
                 SPFE     PMS      R6     R12     R24     R48     R72     R96
                 0.00   23.90  100.00  120.00  130.00    0.00    0.00    0.00

                                         LOSS DATA
     LROPT   STRKR   DLTKR   RTIOL   ERAIN   STRKS   RTIOK   STRTL   CNSTL   ALSMX   RTIMP
         0    0.00    0.00    1.00    0.00    0.00    1.00   -1.00  -89.00    0.00    0.00

        CURVE NO = -89.00  WETNESS =   -1.00  EFFECT CN =   89.00

                                   UNIT HYDROGRAPH DATA
                              TC=  0.00     LAG=   .68

                                       RECESSION DATA
                    STRTQ=    0.00    QRCSN=    0.00    RTIOR= 1.00

      UNIT HYDROGRAPH 20 END OF PERIOD ORDINATES, TC=    0.00 HOURS, LAG=    .68  VOL= 1.00
     261.     788.    1627.    2595.    3115.    3202.    2964.    2548.    1965.    1411.
    1055.     811.     610.     459.     347.     263.     199.     149.     113.      85.
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SUMMARY OF PMF AND ONE-HALF PMF FLOOD ROUTING

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        PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
                  FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)
                        AREA IN SQUARE MILES (SQUARE KILOMETERS)

OPERATION       STATION       AREA    PLAN  RATIO  1  RATIO  2  RATIOS APPLIED TO FLOWS
                                                1.00       .50

HYDROGRAPH AT    10240        6.41      1    31527.    15763.
                         (   16.60)        (  892.73)(  446.37)(

ROUTED TO        10240        6.41      1    25882.    10988.
                         (   16.60)        (  732.89)(  311.15)(
                                        SUMMARY OF DAM SAFETY ANALYSIS

  PLAN  1 ...............                  INITIAL VALUE      SPILLWAY CREST      TOP OF DAM
                            ELEVATION         874.00             874.00             879.80
                            STORAGE           3131.              3131.              4967.
                            OUTFLOW             0.                 0.               1772.

                RATIO      MAXIMUM      MAXIMUM     MAXIMUM     MAXIMUM    DURATION      TIME OF      TIME OF
                 OF       RESERVOIR      DEPTH      STORAGE     OUTFLOW    OVER TOP    MAX OUTFLOW    FAILURE
                 PMF      W.S.ELEV     OVER DAM      AC-FT        CFS        HOURS        HOURS        HOURS

                1.00       883.99        4.19       6502.       25882.       10.50        17.00         0.00
                 .50       881.97        2.17       5686.       10988.        6.83        17.17         0.00
```

PERCENT OF PMF FLOOD ROUTING EQUAL TO SPILLWAY CAPACITY

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PREVIEW OF SEQUENCE OF STREAM NETWORK CALCULATIONS

            RUNOFF HYDROGRAPH AT           10240
            ROUTE HYDROGRAPH TO            10240
            END OF NETWORK
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**********************************
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION      JULY 1978
  LAST MODIFICATION  26 FEB 79
**********************************

RUN DATE* 79/11/28.
    TIME* 07.18.12.

                                   DAM SAFETY INSPECTION - MISSOURI
                                    ELMWOOD CITY LAKE DAM (10240)
                                           PERCENT PMF

                                         JOB SPECIFICATION
                    NQ       NHR      NMIN      IDAY      IHR      IMIN     METRC      IPLT      IPRT     NSTAN
                   300         0        10         0        0         0         0         0         4         0
                                              JOPER       NWT     LROPT     TRACE
                                                  5         0         0         0

                                    MULTI-PLAN ANALYSES TO BE PERFORMED
                                       NPLAN= 1  NRTIO= 9  LRTIO= 1
                      RTIOS=     .20      .21      .22      .23      .24      .25      .26      .27      .28

         *********          *********           *********           *********           *********

                                         SUB-AREA RUNOFF COMPUTATION

                       INPUT PRECIPITATION VALUES, RATIOS AND UNIT HYDROGRAPH PARAMETERS

                                 ISTAQ    ICOMP    IECON    ITAPE     JPLT     JPRT    INAME   ISTAGE    IAUTO
                                 10240        0        0        0        0        0        0        0        0

                                                  HYDROGRAPH DATA
                         IHYDG    IUHG    TAREA     SNAP    TRSDA    TRSPC    RATIO    ISNOW   ISAME   LOCAL
                             1       2     6.35     0.00     6.35     0.00    0.000        0       0       0

                                                    PRECIP DATA
                                   SPFE      PMS       R6      R12      R24      R48      R72      R96
                                   0.00    23.90   100.00   120.00   130.00     0.00     0.00     0.00
      TRSPC COMPUTED BY THE PROGRAM IS  .800

                                                     LOSS DATA
                    LROPT   STRKR   DLTKR   RTIOL   ERAIN   STRKS   RTIOK   STRTL   CNSTL   ALSMX   RTIMP
                        0    0.00    0.00    1.00    0.00    0.00    1.00   -1.00  -89.00    0.00    0.00

                         CURVE NO = -89.00  WETNESS =  -1.00  EFFECT CN =  89.00

                                                 UNIT HYDROGRAPH DATA
                                               TC=  0.00    LAG=   .86

                                                   RECESSION DATA
                                       STRTQ=   0.00    QRCSN=   0.00    RTIOR= 1.00

                                                 END-OF-PERIOD FLOW
          MO.DA  HR.MN  PERIOD   RAIN   EXCS   LOSS   COMP Q     MO.DA  HR.MN  PERIOD   RAIN   EXCS   LOSS   COMP Q
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                                                                              SUM  24.86  23.43   1.92  575827.
                                                                                ( 631.)( 595.)(  36.)(16305.60)

          **********          **********          **********          **********          **********

                                              HYDROGRAPH ROUTING

               ROUTE HYDROGRAPH THROUGH ELMWOOD CITY LAKE DAM

                               ISTAQ   ICOMP   IECON   ITAPE    JPLT    JPRT   INAME  ISTAGE   IAUTO
                               10240       1       0       0       0       0       0       0       0
                                                    ROUTING DATA
                       QLOSS   CLOSS     AVG    IRES   ISAME    IOPT    IPMP            LSTR
                         0.0   0.000    0.30       1       1       0       0               0

                               NSTPS   NSTDL     LAG   AMSKK       X     TSK   STORA  ISPRAT
                                   0       0       0   0.000   0.000   0.000   -874.      -1

    STAGE     874.00    874.50    875.00    876.20    877.00    877.73    878.44    879.12    879.79    880.33
              880.96    881.12    882.56    884.16

     FLOW       0.00     17.00     47.00    133.00    209.00    389.00    710.00   1170.00   1757.00   2573.00
             2928.00   5631.00  14592.00  27222.00

      CAPACITY=      0.        3.      181.      828.     2254.     3131.     3940.     4837.     8734.    14385.

     ELEVATION=    838.      840.      850.      860.      870.      874.      877.      880.      890.      900.

                             CREL   SPWID   COQW    EXPW   ELEVL    COQL   CAREA    EXPL
                            874.0     0.0    0.0     0.0     0.0     0.0     0.0     0.0

                                                   DAM DATA
                                          TOPEL    COQD    EXPD  DAMWID
                                          879.8     0.0     0.0      0.

  PEAK OUTFLOW IS      822. AT TIME  19.17 HOURS

  PEAK OUTFLOW IS      935. AT TIME  19.17 HOURS

  PEAK OUTFLOW IS     1045. AT TIME  19.17 HOURS

  PEAK OUTFLOW IS     1154. AT TIME  19.00 HOURS

  PEAK OUTFLOW IS     1285. AT TIME  19.00 HOURS

  PEAK OUTFLOW IS     1419. AT TIME  19.00 HOURS

  PEAK OUTFLOW IS     1648. AT TIME  19.00 HOURS
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PEAK OUTFLOW IS     1676. AT TIME  18.83 HOURS

PEAK OUTFLOW IS     1822. AT TIME  18.83 HOURS

          **********          **********          **********          **********          **********
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                    PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
                                         FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)
                                              AREA IN SQUARE MILES (SQUARE KILOMETERS)

                                                                     RATIOS APPLIED TO FLOWS
  OPERATION     STATION       AREA    PLAN  RATIO 1  RATIO 2  RATIO 3  RATIO 4  RATIO 5  RATIO 6  RATIO 7  RATIO 8  RATIO 9
                                                .20      .21      .22      .23      .24      .25      .26      .27      .28

  HYDROGRAPH AT   10240       6.35       1    4986.    5235.    5494.    5734.    5983.    6232.    6481.    6731.    6980.
                          (  16.45)         ( 141.18)( 148.24)( 155.30)( 162.36)( 169.42)( 176.48)( 183.54)( 190.59)( 197.66)

  ROUTED TO       10240       6.35       1     822.     935.    1045.    1154.    1285.    1419.    1548.    1676.    1822.
                          (  16.45)         (  23.28)(  26.49)(  29.60)(  32.68)(  36.40)(  40.17)(  43.82)(  47.46)(  51.60)
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                                   SUMMARY OF DAM SAFETY ANALYSIS

PLAN  1 ...............                    INITIAL VALUE     SPILLWAY CREST     TOP OF DAM
                            ELEVATION         874.00             874.00           879.80
                            STORAGE           3131.              3131.            4807.
                            OUTFLOW              0.                 0.            1772.

                RATIO     MAXIMUM      MAXIMUM     MAXIMUM     MAXIMUM    DURATION     TIME OF     TIME OF
                 OF      RESERVOIR      DEPTH      STORAGE     OUTFLOW    OVER TOP   MAX OUTFLOW   FAILURE
                 PMF     W.S.ELEV     OVER DAM      AC-FT        CFS        HOURS       HOURS       HOURS

                 .20      878.51        0.00        4437.        822.        0.00       19.17        0.00
                 .21      878.77        0.00        4489.        935.        0.00       19.17        0.00
                 .22      879.04        0.00        4539.       1045.        0.00       19.17        0.00
                 .23      879.10        0.00        4589.       1154.        0.00       19.00        0.00
                 .24      879.25        0.00        4637.       1285.        0.00       19.00        0.00
                 .25      879.40        0.00        4684.       1419.        0.00       19.00        0.00
                 .26      879.55        0.00        4730.       1548.        0.00       19.00        0.00
                 .27      879.70        0.00        4775.       1676.        0.00       18.83        0.00
                 .28      879.83         .03        4820.       1822.         .83       19.83        0.00
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